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THE WORLD AS I SEE IT
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THE WORLD AS I SEE IT

by
ALBERT EINSTEIN

translated by ALAN HARRIS

LONDON
JOHN LANE THE BODLEY HEAD

*This book is the authorised English translation
of the volume "Mein Weltbild" by Albert Einstein*

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PREFACE

Only individuals have a sense of responsibility —NIETZSCHE

THIS book does not represent a complete collection of the articles, addresses and pronouncements of Albert Einstein, it is a selection made with a definite object, namely, to give a picture of a man. To-day this man is being drawn, contrary to his own intention, into the whirlpool of political passions and contemporary history. As a result, Einstein is experiencing the fate that so many of the great men of history experienced: his character and opinions are being exhibited to the world in an utterly distorted form.

To forestall this fate is the real object of this book. It meets a wish that has constantly been expressed both by Einstein's friends and by the wider public. It contains work belonging to the most various dates—the article on "The International of Science" dates from the year 1922, the address on "The principles of Scientific Research" from 1923, the "Letter to an Arab" from 1930—and the most various spheres, held together by the unity of the personality which stands behind all these utterances. Albert Einstein believes in humanity, in a peaceful world of mutual helpfulness, and in the high mission of science. This book is intended as a plea for this belief at a time which compels every one of us to overhaul his mental attitude and his ideas.

J H

TRANSLATORS' NOTE

In Part V I have had the benefit of the expert supervision of Dr. H. Stafford Hatfield, to whom my thanks are due.

A H.

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THE WORLD AS I SEE IT

The Meaning of Life

WHAT is the meaning of human life, or of organic life altogether? To answer this question at all implies a religion. Is there any sense then, you ask, in putting it? I answer, the man who regards his own life and that of his fellow-creatures as meaningless is not merely unfortunate but almost disqualified for life.

The World as I see it

What an extraordinary situation is that of us mortals! Each of us is here for a brief sojourn, for what purpose he knows not, though he sometimes thinks he feels it. But from the point of view of daily life, without going deeper, we exist for our fellow-men—in the first place for those on whose smiles and welfare all our happiness depends, and next for all those unknown to us personally with whose destinies we are bound up by the tie of sympathy. A hundred times every day I remind myself that my inner and outer life depend on the labours of other men, living and dead, and that I must exert myself in order to give in the same measure as I have received and am still receiving. I am strongly drawn to the simple life and am often oppressed by the feeling that I am engrossing an unnecessary amount of the labour of my fellow-men. I regard class differences as contrary to justice and, in the last resort, based on force. I also consider that plain living is good for everybody, physically and mentally.

my own gait and have never belonged to my country, my home, my friends, or even my immediate family, with my whole heart, in the face of all these ties I have never lost an obstinate sense of detachment, of the need for solitude—a feeling which increases with the years. One is sharply conscious yet without regret, of the limits to the possibility of mutual understanding and sympathy with one's fellow-creatures. Such a person no doubt loses something in the way of geniality and light-heartedness, on the other hand, he is largely independent of the opinions, habits and judgments of his fellows and avoids the temptation to take his stand on such insecure foundations.

My political ideal is that of democracy. Let every man be respected as an individual and no man idolised. It is an irony of fate that I myself have been the recipient of excessive admiration and respect from my fellows through no fault and no merit, of my own. The cause of this may well be the desire, unattainable for many, to understand the one or two ideas to which I have with my feeble powers attained through ceaseless struggle. I am quite aware that it is necessary for the success of any complex undertaking that one man should do the thinking and directing and in general bear the responsibility. But the led must not be compelled, they must be able to choose their leader. An autocratic system of coercion, in my opinion soon degenerates. For force always attracts men of low morality, and I believe it to be an invariable rule that tyrants of genius are succeeded by scoundrels. For this reason I have always been passionately opposed to systems such as we see in Italy and Russia to-day. The thing that has brought discredit upon the prevailing form of democracy in Europe to-day is not to be laid to the door of the democratic idea.

In human freedom in the philosophical sense I am definitely a disbeliever. Everybody acts not only under external compulsion but also in accordance with inner necessity. Schopenhauer's saying, that "a man can do as he will, but not will as he will," has been an inspiration to me since my youth up, and a continual consolation and unfailing well-spring of patience in the face of the hardships of life, my own and others'. This feeling mercifully mitigates the sense of responsibility which so easily becomes paralysing, and it prevents us from taking ourselves and other people too seriously; it conduces to a view of life in which humour, above all, has its due place.

To enquire after the meaning or object of one's own existence or of creation generally has always seemed to me absurd from an objective point of view. And yet everybody has certain ideals which determine the direction of his endeavours and his judgments. In this sense I have never looked upon ease and happiness as ends in themselves—such an ethical basis I call more proper for a herd of swine. The ideals which have lighted me on my way and time after time given me new courage to face life cheerfully, have been Truth, Goodness and Beauty. Without the sense of fellowship with men of like mind, of preoccupation with the objective, the eternally unattainable in the field of art and scientific research, life would have seemed to me empty. The ordinary objects of human endeavour—property, outward success, luxury—have always seemed to me contemptible.

My passionate sense of social justice and social responsibility has always contrasted oddly with my pronounced freedom from the need for direct contact with other human beings and human communities. I gain

my own gait and have never belonged to my country, my home, my friends, or even my immediate family, with my whole heart; in the face of all these ties I have never lost an obstinate sense of detachment, of the need for solitude—a feeling which increases with the years. One is sharply conscious, yet without regret, of the limits to the possibility of mutual understanding and sympathy with one's fellow-creatures. Such a person no doubt loses something in the way of geniality and light-heartedness; on the other hand, he is largely independent of the opinions, habits and judgments of his fellows and avoids the temptation to take his stand on such insecure foundations.

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as such, but to lack of stability on the part of the heads of governments and to the impersonal character of the electoral system. I believe that in this respect the United States of America have found the right way. They have a responsible President who is elected for a sufficiently long period and has sufficient powers to be really responsible. On the other hand, what I value in our political system is the more extensive provision that it makes for the individual in case of illness or need. The really valuable thing in the pageant of human life seems to me not the state but the creative, sentient individual, the personality; it alone creates the noble and the sublime, while the herd as such remains dull in thought and dull in feeling.

This topic brings me to that worst outcrop of the herd nature, the military system, which I abhor. That a man can take pleasure in marching in formation to the strains of a band is enough to make me despise him. He has only been given his big brain by mistake; a backbone was all he needed. This plague-spot of civilisation ought to be abolished with all possible speed. Heroism by order, senseless violence and all the pestilent nonsense that goes by the name of patriotism—how I hate them! War seems to me a mean, contemptible thing. I would rather be hacked in pieces than take part in such an abominable business. And yet so high, in spite of everything, is my opinion of the human race that I believe this bogey would have disappeared long ago, had the sound sense of the nations not been systematically corrupted by commercial and political interests acting through the schools and the Press.

The fairest thing we can experience is the mysterious. It is the fundamental emotion which stands at the cradle of true art and true science. He who knows it not and

can no longer wonder, no longer feel amazement, is as good as dead, a snuffed-out candle. It was the experience of mystery—even if mixed with fear—that engendered religion. A knowledge of the existence of something we cannot penetrate, of the manifestations of the profoundest reason and the most radiant beauty, which are only accessible to our reason in their most elementary forms—it is this knowledge and this emotion that constitute the truly religious attitude, in this sense, and in this alone, I am a deeply religious man. I cannot conceive of a God who rewards and punishes his creatures, or has a will of the type of which we are conscious in ourselves. An individual who should survive his physical death is also beyond my comprehension, nor do I wish it otherwise, such notions are for the fears or absurd egoism of feeble souls. Enough for me the mystery of the eternity of life, and the inkling of the marvellous structure of reality, together with the single-hearted endeavour to comprehend a portion, be it never so tiny, of the reason that manifests itself in nature.

The Liberty of Doctrine—à propos of the Gumbel Case

Academic chairs are many, but wise and noble teachers are few, lecture-rooms are numerous and large, but the number of young people who genuinely thirst after truth and justice is small. Nature scatters her common wares with a lavish hand, but the choice sort she produces but seldom.

We all know that, so why complain? Was it not ever thus and will it not ever thus remain? Certainly, and one must take what nature gives as one finds it. But there is also such a thing as a spirit of the times, an

attitude of mind characteristic of a particular generation, which is passed on from individual to individual and gives a society its particular tone. Each of us has to do his little bit towards transforming this spirit of the times.

Compare the spirit which animated the youth in our universities a hundred years ago with that prevailing to-day. They had faith in the amelioration of human society, respect for every honest opinion, the tolerance for which our classics had lived and fought. In those days men strove for a larger political unity, which at that time was called Germany. It was the students and the teachers at the universities who kept these ideals alive.

To-day also there is an urge towards social progress, towards tolerance and freedom of thought, towards a larger political unity, which we to-day call Europe. But the students at our universities have ceased as completely as their teachers to enshrine the hopes and ideals of the nation. Anyone who looks at our times coolly and dispassionately must admit this.

We are assembled to-day to take stock of ourselves. The external reason for this meeting is the Gumbel case. This apostle of justice has written about unexpiated political crimes with devoted industry, high courage, and exemplary fairness, and has done the community a signal service by his books. And this is the man whom the students, and a good many of the staff, of his university are to-day doing their best to expel.

Political passion cannot be allowed to go to such lengths. I am convinced that every man who reads Herr Gumbel's books with an open mind will get the same impression from them as I have. Men like him are needed if we are ever to build up a healthy political society.

Let every man judge according to his own standards, by what he has himself read, not by what others tell him.

If that happens, this Gumbel case, after an unedifying beginning, may still do good.

Good and Evil

It is right in principle that those should be the best loved who have contributed most to the elevation of the human race and human life. But if one goes on to ask who they are, one finds oneself in no inconsiderable difficulties. In the case of political, and even of religious, leaders, it is often very doubtful whether they have done more good or harm. Hence I most seriously believe that one does people the best service by giving them some elevating work to do and thus indirectly elevating them. This applies most of all to the great artist, but also in a lesser degree to the scientist. To be sure, it is not the fruits of scientific research that elevate a man and enrich his nature, but the urge to understand, the intellectual work, creative or receptive. It would surely be absurd to judge the value of the Talmud, for instance, by its intellectual fruits.

The true value of a human being is determined primarily by the measure and the sense in which he has attained to liberation from the self.

Society and Personality

When we survey our lives and endeavours, we soon observe that almost the whole of our actions and desires are bound up with the existence of other human beings.

We see that our whole nature resembles that of the social animals. We eat food that others have grown, wear clothes that others have made, live in houses that others have built. The greater part of our knowledge and beliefs has been communicated to us by other people through the medium of a language which others have created. Without language our mental capacities would be poor indeed; comparable to those of the higher animals; we have, therefore, to admit that we owe our principal advantage over the beasts to the fact of living in human society. The individual, if left alone from birth, would remain primitive and beast-like in his thoughts and feelings to a degree that we can hardly conceive. The individual is what he is and has the significance that he has not so much in virtue of his individuality, but rather as a member of a great human society, which directs his material and spiritual existence from the cradle to the grave.

A man's value to the community depends primarily on how far his feelings, thoughts and actions are directed towards promoting the good of his fellows. We call him good or bad according to how he stands in this matter. It looks at first sight as if our estimate of a man depended entirely on his social qualities.

And yet such an attitude would be wrong. It is clear that all the valuable things, material, spiritual and moral, which we receive from society can be traced back through countless generations to certain creative individuals. The use of fire, the cultivation of edible plants, the steam engine;—each was discovered by one man.

Only the individual can think, and thereby create new values for society, nay, even set up new moral standards to which the life of the community conforms.

Without creative, independently thinking and judging personalities the upward development of society is as unthinkable as the development of the individual personality without the nourishing soil of the community.

The health of society thus depends quite as much on the independence of the individuals composing it as on their close political cohesion. It has been said very justly that Græco-European-American culture as a whole, and in particular its brilliant flowering in the Italian Renaissance, which put an end to the stagnation of mediæval Europe, is based on the liberation and comparative isolation of the individual.

Let us now consider the times in which we live. How does society fare, how the individual? The population of the civilised countries is extremely dense as compared with former times; Europe to-day contains about three times as many people as it did a hundred years ago. But the number of great men has decreased out of all proportion. Only a few individuals are known to the masses as personalities, through their creative achievements. Organisation has to some extent taken the place of the great man, particularly in the technical sphere, but also to a very perceptible extent in the scientific.

The lack of outstanding figures is particularly striking in the domain of art. Painting and music have definitely degenerated and largely lost their popular appeal. In politics not only are leaders lacking, but the independence of spirit and the sense of justice of the citizen have to a great extent declined. The democratic, parliamentary régime, which is based on such independence, has in many places been shaken, dictatorships have sprung up and are tolerated, because men's sense of the

dignity and the rights of the individual is no longer strong enough. In two weeks the sheep-like masses can be worked up by the newspapers into such a state of excited fury that the men are prepared to put on uniform and kill and be killed, for the sake of the worthless aims of a few interested parties. Compulsory military service seems to me the most disgraceful symptom of that deficiency in personal dignity from which civilised mankind is suffering to-day. No wonder there is no lack of prophets who prophesy the early eclipse of our civilisation. I am not one of these pessimists, I believe that better times are coming. Let me shortly state my reasons for such confidence.

In my opinion, the present symptoms of decadence are explained by the fact that the development of industry and machinery has made the struggle for existence very much more severe, greatly to the detriment of the free development of the individual. But the development of machinery means that less and less work is needed from the individual for the satisfaction of the community's needs. A planned division of labour is becoming more and more of a crying necessity, and this division will lead to the material security of the individual. This security and the spare time and energy which the individual will have at his command can be made to further his development. In this way the community may regain its health, and we will hope that future historians will explain the morbid symptoms of present-day society as the childhood ailments of an aspiring humanity, due entirely to the excessive speed at which civilisation was advancing.

Address at the Grave of H. A. Lorentz

It is as the representative of the German-speaking academic world and in particular the Prussian Academy of Sciences, but above all as a pupil and affectionate admirer that I stand at the grave of the greatest and noblest man of our times. His genius was the torch which lighted the way from the teachings of Clerk Maxwell to the achievements of contemporary physics, to the fabric of which he contributed valuable materials and methods.

His life was ordered like a work of art down to the smallest detail. His never-failing kindness and magnanimity and his sense of justice, coupled with an intuitive understanding of people and things, made him a leader in any sphere he entered. Everyone followed him gladly, for they felt that he never set out to dominate but always simply to be of use. His work and his example will live on as an inspiration and guide to future generations.

H. A. Lorentz's work in the cause of International Co-operation

With the extensive specialisation of scientific research which the nineteenth century brought about, it has become rare for a man occupying a leading position in one of the sciences to manage at the same time to do valuable service to the community in the sphere of international organisation and international politics. Such service demands not only energy, insight and a reputation based on solid achievements, but also a freedom from national prejudice and a devotion to the common ends of all, which have become rare in our

times I have met no one who combined all these qualities in himself so perfectly as H. A. Lorentz. The marvellous thing about the effect of his personality was this —Independent and headstrong natures, such as are particularly common among men of learning, do not readily bow to another's will and for the most part only accept his leadership grudgingly. But when Lorentz is in the presidential chair, an atmosphere of happy co-operation is invariably created, however much those present may differ in their aims and habits of thought. The secret of this success lies not only in his swift comprehension of people and things and his marvellous command of language, but above all in this, that one feels that his whole heart is in the business in hand, and that when he is at work, he has room for nothing else in his mind. Nothing disarms the recalcitrant so much as this.

Before the War Lorentz's activities in the cause of international relations were confined to presiding at congresses of physicists. Particularly noteworthy among these were the Solvay Congresses, the first two of which were held at Brussels in 1909 and 1912. Then came the European war, which was a crushing blow to all who had the improvement of human relations in general at heart. Even before the war was over, and still more after its end, Lorentz devoted himself to the work of reconciliation. His efforts were especially directed towards the re-establishment of fruitful and friendly co-operation between men of learning and scientific societies. An outsider can hardly conceive what uphill work this is. The accumulated resentment of the war period has not yet died down and many influential men persist in the irreconcilable attitude into which they allowed themselves to be driven by the

pressure of circumstances. Hence Lorentz's efforts resemble those of a doctor with a recalcitrant patient who refuses to take the medicines carefully prepared for his benefit.

But Lorentz is not to be deterred, once he has recognised a course of action as the right one. The moment the war was over, he joined the governing body of the "Conseil de recherche" which was founded by the savants of the victorious countries, and from which the savants and learned societies of the Central Powers were excluded. His object in taking this step, which caused great offence to the academic world of the Central Powers, was to influence this institution in such a way that it could be expanded into something truly international. He and other right-minded men succeeded, after repeated efforts, in securing the removal of the offensive exclusion-clause from the statutes of the "Conseil." The goal, which is the restoration of normal and fruitful co-operation between learned societies, is, however, not yet attained, because the academic world of the Central Powers, exasperated by nearly ten years of exclusion from practically all international gatherings, has got into a habit of keeping itself to itself. Now, however, there are good grounds for hoping that the ice will soon be broken, thanks to the tactful efforts of Lorentz, prompted by pure enthusiasm for the good cause.

Lorentz has also devoted his energies to the service of international cultural ends in another way, by consenting to serve on the League of Nations Commission for international intellectual co-operation, which was called into existence some five years ago with Bergson as chairman. For the last year Lorentz has presided over the Commission, which, with the active support of its

subordinate, the Paris Institute, is to act as a go-between in the domain of intellectual and artistic work among the various spheres of culture. There too the beneficent influence of this intelligent, humane and modest personality, whose unspoken but faithfully followed advice is, "Not mastery but service," will lead people in the right way.

May his example contribute to the triumph of that spirit!

In Honour of Arnold Berliner's Seventieth Birthday

(Arnold Berliner is the editor of the periodical *Die Naturwissenschaften*.)

I should like to take this opportunity of telling my friend Berliner and the readers of this paper why I rate him and his work so highly. It has to be done here because it is one's only chance of getting such things said; since our training in objectivity has led to a taboo on everything personal, which we mortals may only transgress on quite exceptional occasions such as the present one.

And now, after this dash for liberty, back to the objective! The province of scientifically determined fact has been enormously extended, theoretical knowledge has become vastly more profound in every department of science. But the assimilative power of the human intellect is and remains strictly limited. Hence it was inevitable that the activity of the individual investigator should be confined to a smaller and smaller section of human knowledge. Worse still, as a result of this specialisation it is becoming increasingly difficult for even a rough general grasp of science as a whole, without which the true spirit of research is inevitably

handicapped, to keep pace with progress. A situation is developing similar to the one symbolically represented in the Bible by the story of the Tower of Babel. Every serious scientific worker is painfully conscious of this involuntary relegation to an ever-narrowing sphere of knowledge, which is threatening to deprive the investigator of his broad horizon and degrade him to the level of a mechanic.

We have all suffered under this evil, without making any effort to mitigate it. But Berliner has come to the rescue, as far as the German-speaking world is concerned, in the most admirable way. He saw that the existing popular periodicals were sufficient to instruct and stimulate the layman, but he also saw that a first-class, well-edited organ was needed for the guidance of the scientific worker who desired to be put sufficiently *au courant* of developments in scientific problems, methods and results to be able to form a judgment of his own. Through many years of hard work he has devoted himself to this object with great intelligence and no less great determination, and done us all, and science a service for which we cannot be too grateful.

It was necessary for him to secure the co-operation of successful scientific writers and induce them to say what they had to say in a form as far as possible intelligible to non-specialists. He has often told me of the fights he had in pursuing this object, the difficulties of which he once described to me in the following riddle. Question: What is a scientific author? Answer: A cross between a mimosa and a porcupine.¹ Berliner's achievement would have been impossible but for the peculiar intensity of his longing for a clear, compre-

Do not be angry with me for this and scold me, my dear Berliner. A serious minded man enjoys a good laugh now and then.

sive view of the largest possible area of scientific country. This feeling also drove him to produce a text-book of physics, the fruit of many years of strenuous work, of which a medical student said to me the other day "I don't know how I should ever have got a clear idea of the principles of modern physics in the time at my disposal without this book."

Berliner's fight for clarity and comprehensiveness of outlook has done a great deal to bring the problems, methods and results of science home to many people's minds. The scientific life of our time is simply inconceivable without his paper. It is just as important to make knowledge live and to keep it alive as to solve specific problems. We are all conscious of what we owe to Arnold Berliner.

Popper-Lynkæus was more than a brilliant engineer and writer. He was one of the few outstanding personalities who embody the conscience of a generation. He has drummed it into us that society is responsible for the fate of every individual and shown us a way to translate the consequent obligation of the community into fact. The community or state was no fetish to him, he based its right to demand sacrifices of the individual entirely on its duty to give the individual personality a chance of harmonious development.

Obituary of the Surgeon, M. Katzenstein

During the eighteen years I spent in Berlin I had few close friends, and the closest was Professor Katzenstein. For more than ten years I spent my leisure hours ~~during the summer months with him, mostly on his~~ delightful yacht. There we confided our experiences,

ambitions, emotions to each other. We both felt that this friendship was not only a blessing because each understood the other, was enriched by him, and found in him that responsive echo so essential to anybody who is truly alive; it also helped to make both of us more independent of external experience, to objectivise it more easily.

I was a free man, bound neither by many duties nor by harassing responsibilities; my friend, on the contrary, was never free from the grip of urgent duties and anxious fears for the fate of those in peril. If, as was invariably the case, he had performed some dangerous operations in the morning, he would ring up on the telephone, immediately before we got into the boat, to enquire after the condition of the patients about whom he was worried; I could see how deeply concerned he was for the lives entrusted to his care. It was marvellous that this shackled outward existence did not clip the wings of his soul; his imagination and his sense of humour were irrepressible. He never became the typical conscientious North-German, whom the Italians in the days of their freedom used to call *bestia seriosa*. He was sensitive as a youth to the tonic beauty of the lakes and woods of Brandenburg, and as he sailed the boat with an expert hand through these beloved and familiar surroundings he opened the secret treasure-chamber of his heart to me—he spoke of his experiments, scientific ideas, and ambitions. How he found time and energy for them was always a mystery to me; but the passion for scientific enquiry is not to be crushed by any burdens. The man who is possessed with it perishes sooner than it does.

There were two types of problems that engaged his attention. The first forced itself on him out of the

necessities of his practice. Thus he was always thinking out new ways of inducing healthy muscles to take the place of lost ones, by ingenious transplantation of tendons. He found this remarkably easy, as he possessed an uncommonly strong spatial imagination and a remarkably sure feeling for mechanism. How happy he was when he had succeeded in making somebody fit for normal life by putting right the muscular system of his face, foot or arm! And the same when he avoided an operation, even in cases which had been sent to him by physicians for surgical treatment (in cases of gastric ulcer by neutralising the pepsin). He also set great store by the treatment of peritonitis by an anti-toxic coli-serum which he discovered, and rejoiced in the successes he achieved with it. In talking of it he often lamented the fact that this method of treatment was not endorsed by his colleagues.

The second group of problems had to do with the common conception of an antagonism between different sorts of tissue. He believed that he was here on the track of a general biological principle of widest application, whose implications he followed out with admirable boldness and persistence. Starting out from this basic notion he discovered that osteomyelom and periosteum prevent each other's growth if they are not separated from each other by bone. In this way he succeeded in explaining hitherto inexplicable cases of wounds failing to heal, and in bringing about a cure.

This general notion of the antagonism of the tissues, especially of epithelium and connective tissue, was the subject to which he devoted his scientific energies, especially in the last ten years of his life. Experiments on animals and a systematic investigation of the growth of tissues in a nutrient fluid were carried out side by

side. How thankful he was, with his hands tied as they were by his duties, to have found such an admirable and infinitely enthusiastic fellow-worker in Fräulein Knake! He succeeded in securing wonderful results bearing on the factors which favour the growth of epithelium at the expense of that of connective tissue, results which may well be of decisive importance for the study of cancer. He also had the pleasure of inspiring his own son to become his intelligent and independent fellow-worker, and of exciting the warm interest and co-operation of Sauerbruch just in the last years of his life, so that he was able to die with the consoling thought that his life's work would not perish but would be vigorously continued on the lines he had laid down.

I for my part am grateful to fate for having given me this man, with his inexhaustible goodness and high creative gifts, for a friend.

Congratulations to Dr. Solj

I am delighted to be able to offer you, Dr. Solj, the heartiest congratulations, the congratulations of Lessing College of which you have become an indispensable pillar, and the congratulations of all who are convinced of the need for close contact between science and art and the public which is hungry for spiritual nourishment.

You have not hesitated to apply your energies to a field where there are no laurels to be won, but quiet, loyal work to be done in the interests of the general standard of intellectual and spiritual life, which is in peculiar danger to-day owing to a variety of circumstances. Exaggerated respect for athletics, an excess of

coarse impressions which the complication of life through the technical discoveries of recent years has brought with it, the increased severity of the struggle for existence due to the economic crisis, the brutalisation of political life—all these factors are hostile to the ripening of the character and the desire for real culture, and stamp our age as barbarous, materialistic and superficial. Specialisation in every sphere of intellectual work is producing an ever-widening gulf between the intellectual worker and the non-specialist, which makes it more difficult for the life of the nation to be fertilised and enriched by the achievements of art and science.

But contact between the intellectual and the masses must not be lost. It is necessary for the elevation of society and no less so for renewing the strength of the intellectual worker, for the flower of science does not grow in the desert. For this reason you, Herr Solf, have devoted a portion of your energies to Lessing College, and we are grateful to you for doing so. And we wish you further success and happiness in your work for this noble cause.

Of Wealth

I am absolutely convinced that no wealth in the world can help humanity forward, even in the hands of the most devoted worker in this cause. The example of great and pure characters is the only thing that can produce fine ideas and noble deeds. Money only appeals to selfishness and always tempts its owners irresistibly to abuse it.

Can anyone imagine Moses, Jesus or Gandhi armed with the money-bags of Carnegie?

Education and Educators

A letter

Dear Miss —

I have read about sixteen pages of your manuscript and it made me—smile. It is clever, well observed, honest, it stands on its own feet up to a point, and yet it is so typically feminine, by which I mean derivative and vitiated by personal rancour. I suffered exactly the same treatment at the hands of my teachers, who disliked me for my independence and passed me over when they wanted assistants (I must admit that I was somewhat less of a model student than you). But it would not have been worth my while to write anything about my school life, still less would I have liked to be responsible for anyone's printing or actually reading it. Besides, one always cuts a poor figure if one complains about others who are struggling for their place in the sun too after their own fashion.

Therefore pocket your temperament and keep your manuscript for your sons and daughters, in order that they may derive consolation from it and—not give a damn for what their teachers tell them or think of them.

Incidentally I am only coming to Princeton to research, not to teach. There is too much education altogether, especially in American schools. The only rational way of educating is to be an example—of what to avoid, if one can't be the other sort.

With best wishes.

To the Schoolchildren of Japan

In sending this greeting to you Japanese school-children, I can lay claim to a special right to do so. For

I have myself visited your beautiful country, seen its cities and houses, its mountains and woods, and in Japanese boys who had learnt from them to love country. A big fat book full of coloured drawings of Japanese children lies always on my table.

If you get my message of greeting from all distance, bethink you that ours is the first age in history to bring about friendly and understanding intercourse between people of different countries, in former times nations passed their lives in mutual ignorance, and each hated or feared one another. May the spirit of brotherly understanding gain ground more and more among them. With this in mind I, an old man, greet you Japanese schoolchildren from afar and hope your generation may some day put mine to shame.

Teachers and Pupils

An address to children

(The principal art of the teacher is to awaken the joy in creation and knowledge.)

My dear Children,

I rejoice to see you before me to-day, happy youth of a sunny and fortunate land.

Bear in mind that the wonderful things you learn in your schools are the work of many generations, produced by enthusiastic effort and infinite labour in every country of the world. All this is put into your hands as your inheritance in order that you may receive it, honour it, add to it, and one day faithfully hand it on to your children. Thus do we mortals achieve immortality in the permanent things which we create in common.

If you always keep that in mind you will find a meaning in life and work and acquire the right attitude towards other nations and ages.

Paradise Lost

As late as the seventeenth century the savants and artists of all Europe were so closely united by the bond of a common ideal that co-operation between them was scarcely affected by political events. This unity was further strengthened by the general use of the Latin language.

To-day we look back at this state of affairs as at a lost paradise. The passions of nationalism have destroyed this community of the intellect, and the Latin language, which once united the whole world, is dead. The men of learning have become the chief mouthpieces of national tradition and lost their sense of an intellectual commonwealth.

Nowadays we are faced with the curious fact that the politicians, the practical men of affairs, have become the exponents of international ideas. It is they who have created the League of Nations.

Religion and Science

Every thing that the human race has done and thought is concerned with the satisfaction of felt needs and the assuagement of pain. One has to keep this constantly in mind if one wishes to understand spiritual movements and their development. Feeling and desire are the motive forces behind all human endeavour and human creation, in however exalted a guise the latter may present itself to us. Now what are the feelings

and needs that have led men to religious thought and belief in the widest sense of the words. A little consideration will suffice to show us that the most varying emotions preside over the birth of religious thought and experience (With primitive man it is above all fear that evokes religious notions—fear of hunger, wild beasts, sickness, death. Since at this stage of existence understanding of causal connexions is usually poorly developed, the human mind creates for itself more or less analogous beings on whose wills and actions these fearful happenings depend. One's object now is to secure the favour of these beings by carrying out actions and offering sacrifices which, according to the tradition handed down from generation to generation, propitiate them or make them well disposed towards a mortal. I am speaking now of the religion of fear. This, though not created, is in an important degree stabilised by the formation of a special priestly caste which sets up as a mediator between the people and the beings they fear, and erects a hegemony on this basis. In many cases the leader or ruler whose position depends on other factors, or a privileged class, combines priestly functions with its secular authority in order to make the latter more secure, or the political rulers and the priestly caste make common cause in their own interests.)

The social feelings are another source of the crystallisation of religion. Fathers and mothers and the leaders of larger human communities are mortal and fallible. The desire for guidance, love and support prompts men to form the social or moral conception of God. Thus is the God of Providence who protects, disposes, rewards and punishes, the God who, according to the width of the believer's outlook, loves and cherishes the life of the tribe or of the human race, or even life as

such, the comforter in sorrow and unsatisfied longing, who preserves the souls of the dead. This is the social or moral conception of God.

The Jewish scriptures admirably illustrate the development from the religion of fear to moral religion, which is continued in the New Testament. The religions of all civilised peoples, especially the peoples of the Orient, are primarily moral religions. The development from a religion of fear to moral religion is a great step in a nation's life. That primitive religions are based entirely on fear and the religions of civilised peoples purely on morality is a prejudice against which we must be on our guard. The truth is that they are all intermediate types, with this reservation, that on the higher levels of social life the religion of morality predominates.

Common to all these types is the anthropomorphic character of their conception of God. Only individuals of exceptional endowments and exceptionally high-minded communities, as a general rule, get in any real sense beyond this level. But there is a third state of religious experience which belongs to all of them, even though it is rarely found in a pure form, and which I will call cosmic religious feeling. It is very difficult to explain this feeling to any one who is entirely without it, especially as there is no anthropomorphic conception of God corresponding to it.

The individual feels the nothingness of human desires and aims and the sublimity and marvellous order which reveal themselves both in nature and in the world of thought. He looks upon individual existence as a sort of prison and wants to experience the universe as a single significant whole. The beginnings of cosmic religious feeling already appear in earlier stages of development, e.g., in many of the Psalms of David and

in some of the Prophets. Buddhism, as we have learnt from the wonderful writings of Schopenhauer especially, contains a much stronger element of it.

The religious geniuses of all ages have been distinguished by this kind of religious feeling, which knows no dogma and no God conceived in man's image; so that there can be no church whose central teachings are based on it. Hence it is precisely among the heretics of every age that we find men who were filled with the highest kind of religious feeling and were in many cases regarded by their contemporaries as atheists, sometimes also as saints. Looked at in this light, men like Democritus, Francis of Assisi, and Spinoza are closely akin to one another.

How can cosmic religious feeling be communicated from one person to another, if it can give rise to no definite notion of a God and no theology? In my view, it is the most important function of art and science to awaken this feeling and keep it alive in those who are capable of it.

(We thus arrive at a conception of the relation of science to religion very different from the usual one. When one views the matter historically one is inclined to look upon science and religion as irreconcilable antagonists, and for a very obvious reason. The man who is thoroughly convinced of the universal operation of the law of causation cannot for a moment entertain the idea of a being who interferes in the course of events—that is, if he takes the hypothesis of causality really seriously. He has no use for the religion of fear and equally little for social or moral religion. A God who rewards and punishes is unconceivable to him for the simple reason that a man's actions are determined by necessity, external and internal, so that in God's eyes

he cannot be responsible, any more than an inanimate object is responsible for the motions it goes through. Hence science has been charged with undermining morality, but the charge is unjust. A man's ethical behaviour should be based effectually on sympathy, education, and social ties, no religious basis is necessary. Man would indeed be in a poor way if he had to be restrained by fear and punishment and hope of reward after death.)

It is therefore easy to see why the churches have always fought science and persecuted its devotees. On the other hand I maintain that cosmic religious feeling is the strongest and noblest incitement to scientific research. Only those who realise the immense efforts and, above all, the devotion which pioneer work in theoretical science demands, can grasp the strength of the emotion out of which alone such work, remote as it is from the immediate realities of life, can issue. What a deep conviction of the rationality of the universe and what a yearning to understand, were it but a feeble reflection of the mind revealed in this world, Kepler and Newton must have had to enable them to spend years of solitary labour in disentangling the principles of celestial mechanics! Those whose acquaintance with scientific research is derived chiefly from its practical results easily develop a completely false notion of the mentality of the men who, surrounded by a sceptical world, have shown the way to those like-minded with themselves, scattered through the earth and the centuries. Only one who has devoted his life to similar ends can have a vivid realisation of what has inspired these men and given them the strength to remain true to their purpose in spite of countless failures. It is cosmic religious feeling that

gives a man strength of this sort. A contemporary has said, not unjustly, that in this materialistic age of ours the serious scientific workers are the only profoundly religious people.)

The Religiousness of Science

You will hardly find one among the profounder sort of scientific minds without a peculiar religious feeling of his own. But it is different from the religion of the naive man. For the latter God is a being from whose care one hopes to benefit and whose punishment one fears, a sublimation of a feeling similar to that of a child for its father, a being to whom one stands to some extent in a personal relation, however deeply it may be tinged with awe.

But the scientist is possessed by the sense of universal causation. The future, to him, is every whit as necessary and determined as the past. There is nothing divine about morality, it is a purely human affair. His religious feeling takes the form of a rapturous amazement at the harmony of natural law, which reveals an intelligence of such superiority that, compared with it, all the systematic thinking and acting of human beings is an utterly insignificant reflection. This feeling is the guiding principle of his life and work, in so far as he succeeds in keeping himself from the shackles of selfish desire. It is beyond question closely akin to that which has possessed the religious geniuses of all ages.

The Plight of Science

The German-speaking countries are menaced by a danger to which those in the know are in duty bound

has been paid for by the martyr's blood of pure great men, for whose sake Italy is still loved and honored to-day

be it from me to argue with you about what aids on human liberty may be justified by reasons state But the pursuit of scientific truth, detached from the practical interests of everyday life, ought to be treated as sacred by every government and it is the highest interests of all that honest servants of the state should be left in peace This is also undoubtedly the interests of the Italian state and its prestige in the eyes of the world

hoping that my request will not fall on deaf ears, I am, etc

A E

Interviewers

To be called to account publicly for everything one has said, even in jest, an excess of high spirits or momentary anger, fatal as it must be in the end, is yet up to a point reasonable and natural But to be called to account publicly for what others have said in one's name, when one cannot defend oneself, is indeed a dread predicament 'But who suffers such a dreadful fate,' you will ask Well, everyone who is of sufficient interest to the public to be pursued by interviewers You smile incredulously, but I have had plenty of direct experience and will tell you about it

Imagine the following situation One morning a reporter comes to you and asks you in a friendly way to tell him something about your friend N At first you no doubt feel something approaching indignation

THE WORLD AS

at such a proposal. But of the American nation, is no escape. If you have sense of responsibility, writes "I asked self to the sphere of politics. For about him. Bio-operation of the great country. This in itselfates in the business of regulating conclusions, all efforts directed towards this give bound to remain more or less ineffectual.

I thank you most heartily for this reception and, in particular, the men of learning this country for the cordial and friendly welcome have received from them. I shall always look these two months with pleasure and gratitude.

The University Course at Davos

Senatores boni viri, senatus autem bestia. So a of mine, a Swiss professor, once wrote in his irrital way to a university faculty which had annoyed. Communities tend to be less guided than by conscience and a sense of responsibility. What fruitful source of suffering to mankind this fact. It is the cause of wars and every kind of oppression which fill the earth with pain, sighs, and bitterness.

And yet nothing truly valuable can be achieved except by the unselfish co-operation of many individuals. Hence the man of good will is never happier than when some communal enterprise is afoot and launched at the cost of heavy sacrifices, with the single object of promoting life and culture.

Such pure joy was mine when I heard about the university courses at Davos. A work of rescue is being carried out there, with intelligence and a wise moderation, which is based on a grave need, though it may no

need that is immediately obvious to everyone. When a young man goes to this valley with his hopes on the healing power of its sunny mountains and wins his bodily health. But thus withdrawn for long periods from the will-hardening discipline of normal work and a prey to morbid reflection on his physical condition, he easily loses the power of mental effort and the sense of being able to hold his own in the struggle for existence. He becomes a sort of hot-house plant and, when his body is cured, often finds it difficult to get back to normal life. Interruption of intellectual training in the formative period of youth is very apt to leave a gap which can hardly be filled later.

Yet, as a general rule, intellectual work in moderation, far from retarding cure, indirectly helps it forward, just as moderate physical work does. It is in this knowledge that the university courses are being instituted, with the object not merely of preparing these young people for a profession but of stimulating them to intellectual activity as such. They are to provide work, training and hygiene in the sphere of the mind. Let us not forget that this enterprise is admirably calculated to establish such relations between members of different nations as are favourable to the growth of a common European feeling. The effects of the new institution in this direction are likely to be all the more advantageous from the fact that the circumstances of its birth rule out every sort of political purpose. The best way to serve the cause of internationalism is by co-operating in some life-giving work. From all these points of view I rejoice that the energy and intelligence of the founders of the university courses at Davos have already attained such a measure of success that the enterprise has outgrown the troubles

of infancy May it prosper, enriching the
of numbers of admirable human beings and res-
many from the poverty of sanatorium life

Congratulations to a Critic

To see with one's own eyes, to feel and judge with-
succumbing to the suggestive power of the fashion
the day, to be able to express what one has seen
in a snappy sentence or even in a cunningly wro-
word—is that not glorious? Is it not a proper sul-
for congratulation?

Greeting to G. Bernard Shaw

There are few enough people with sufficient indepen-
dence to see the weaknesses and follies of their conten-
poraries and remain themselves untouched by
And these isolated few usually soon lose their zeal
putting things to rights when they have come face
face with human obduracy Only to a tiny minority
it given to fascinate their generation by subtle
and grace and to hold the mirror up to it by the
personal agency of art To-day I salute with
emotion the supreme master of this method, who
delighted—and educated—us all

Some Notes on my American Impressions

I must redeem my promise to say something
my impressions of this country That is not altogether
easy for me For it is not easy to take up the attitude
of an impartial observer when one is received with
such kindness and undeserved respect as I have been
America First of all let me say something on this head

cult of individual personalities is always, in my
 unjustified. To be sure, nature distributes her
 variously among her children. But there are plenty
 of well-endowed ones too, thank God, and I am
 convinced that most of them live quiet, un-
 derd lives. It strikes me as unfair, and even in bad
 to select a few of them for boundless admiration,
 tributing superhuman powers of mind and character
 to them. This has been my fate, and the contrast
 between the popular estimate of my powers and
 my achievements and the reality is simply grotesque. The
 consciousness of this extraordinary state of affairs would
 be unbearable but for one great consoling thought: it is
 a welcome symptom in an age which is commonly
 denounced as materialistic, that it makes heroes of men
 whose ambitions lie wholly in the intellectual and
 moral sphere. This proves that knowledge and justice
 are ranked above wealth and power by a large section
 of the human race. My experience teaches me that
 this idealistic outlook is particularly prevalent in
 America, which is usually decried as a particularly
 materialistic country. After this digression I come to
 my proper theme, in the hope that no more weight
 will be attached to my modest remarks than they
 deserve.

What first strikes the visitor with amazement is the
 superiority of this country in matters of technics and
 organisation. Objects of everyday use are more solid
 than in Europe, houses infinitely more convenient in
 arrangement. Everything is designed to save human
 labour. Labour is expensive, because the country is
 sparsely inhabited in comparison with its natural
 resources. The high price of labour was the stimulus
 which evoked the marvellous development of technical

devices and methods of work. The opposite extreme is illustrated by over-populated China or India, where the low price of labour has stood in the way of the development of machinery. Europe is half-way between the two. Once the machine is sufficiently highly developed it becomes cheaper in the end than the cheapest labour. Let the Fascists in Europe, who desire on narrow-minded political grounds to see their own particular countries more densely populated, take heed of this. The anxious care with which the United States keep out foreign goods by means of prohibitive tariffs certainly contrasts oddly with this notion. But an innocent visitor must not be expected to rack his brains too much, and, when all is said and done, it is not absolutely certain that every question admits of a rational answer.

The second thing that strikes a visitor is the joyous, positive attitude to life. The smile on the faces of the people in photographs is symbolical of one of the American's greatest assets. He is friendly, confident, optimistic, and—without envy. The European finds intercourse with Americans easy and agreeable.

Compared with the American, the European is more critical, more self-conscious, less good-hearted and helpful, more isolated, more fastidious in his amusements and his reading, generally more or less of a pessimist.

Great importance attaches to the material comforts of life, and peace, freedom from care, security are all sacrificed to them. The American lives for ambition, the future, more than the European. Life for him is always becoming, never being. In this respect he is even further removed from the Russian and the Asiatic than the European is. But there is another

respect in which he resembles the Asiatic more than the European does he is less of an individualist than the European—that is, from the psychological, not the economic, point of view

More emphasis is laid on the “we” than the “I”. As a natural corollary of this, custom and convention are very powerful, and there is much more uniformity both in outlook on life and in moral and æsthetic ideas among Americans than among Europeans. This fact is chiefly responsible for America’s economic superiority over Europe. Co-operation and the division of labour are carried through more easily and with less friction than in Europe, whether in the factory or the university or in private good works. This social sense may be partly due to the English tradition.

In apparent contradiction to this stands the fact that the activities of the state are comparatively restricted as compared with Europe. The European is surprised to find the telegraph, the telephone, the railways and the schools predominantly in private hands. The more social attitude of the individual, which I mentioned just now, makes this possible here. Another consequence of this attitude is that the extremely unequal distribution of property leads to no intolerable hardships. The social conscience of the rich man is much more highly developed than in Europe. He considers himself obliged as a matter of course to place a large portion of his wealth, and often of his own energies too, at the disposal of the community, and public opinion, that all-powerful force, imperiously demands it of him. Hence the most important cultural functions can be left to private enterprise and the part played by the state in this country is, comparatively, a very restricted one.

The prestige of government has undoubtedly been lowered considerably by the Prohibition laws. For nothing is more destructive of respect for the government and the law of the land than passing laws which cannot be enforced. It is an open secret that the dangerous increase of crime in this country is closely connected with this.

There is also another way in which Prohibition, in my opinion, has led to the enfeeblement of the state. The public-house is a place which gives people a chance to exchange views and ideas on public affairs. As far as I can see, people here have no chance of doing this, the result being that the Press, which is mostly controlled by definite interests, has an excessive influence over public opinion.

The over-estimation of money is still greater in this country than in Europe, but appears to me to be on the decrease. It is at last beginning to be realised that great wealth is not necessary for a happy and satisfactory life.

As regards artistic matters, I have been genuinely impressed by the good taste displayed in the modern buildings and in articles of common use; on the other hand the visual arts and music have little place in the life of the nation as compared with Europe.

I have a warm admiration for the achievements of American institutes of scientific research. We are unjust in attempting to ascribe the increasing superiority of American research-work exclusively to superior wealth; zeal, patience, a spirit of comradeship and a talent for co-operation play an important part in its successes. One more observation to finish up with. The United States are the most powerful technically advanced country in the world to-day. Their influence on the shaping of international relations is absolutely

incalculable. But America is a large country and its people have so far not shown much interest in great international problems, among which the problem of disarmament occupies first place to-day. This must be changed, if only in the essential interests of the Americans. The last war has shown that there are no longer any barriers between the continents and that the destinies of all countries are closely interwoven. The people of this country must realise that they have a great responsibility in the sphere of international politics. The part of passive spectator is unworthy of this country and is bound in the end to lead to disaster all round.

Reply to the Women of America

An American Women's League felt called upon to protest against Einstein's visit to their country. They received the following answer.

Never yet have I experienced from the fair sex such energetic rejection of all advances; or if I have, never from so many at once.

But are they not quite right, these watchful citizenesses? Why should one open one's doors to a person who devours hard-boiled capitalists with as much appetite and gusto as the Cretan Minotaur in days gone by devoured luscious Greek maidens, and on top of that is low-down enough to reject every sort of war, except the unavoidable war with one's own wife? Therefore give heed to your clever and patriotic women-folk and remember that the Capitol of mighty Rome was once saved by the cackling of its faithful geese.

PART II

POLITICS AND PACIFISM

POLITICS AND PACIFISM

Peace

THE importance of securing international peace was recognised by the really great men of former generations. But the technical advances of our times have turned this ethical postulate into a matter of life and death for civilised mankind to-day, and made the taking of an active part in the solution of the problem of peace a moral duty which no conscientious man can shirk.

One has to realise that the powerful industrial groups concerned in the manufacture of arms are doing their best in all countries to prevent the peaceful settlement of international disputes, and that rulers can only achieve this great end if they are sure of the vigorous support of the majority of their peoples. In these days of democratic government the fate of the nations hangs on themselves, each individual must always bear that in mind.

The Pacifist Problem

Ladies and Gentlemen,

I am very glad of this opportunity of saying a few words to you about the problem of pacifism. The course of events in the last few years has once more shown us how little we are justified in leaving the struggle against armaments and against the war spirit to the governments. On the other hand, the formation of large organisations with a large membership can of

itself bring us very little nearer to our goal. In opinion, the best method in this case is the violent of conscientious objection, with the aid of organisation for giving moral and material support to the courageous conscientious objectors in each country. In this way may succeed in making the problem of pacifism acute one, a real struggle which attracts forceful nature. It is an illegal struggle, but a struggle for people's rights against their governments in so far as the latter demand criminal acts of the citizen.

Many who think themselves good pacifists will, at this out-and-out pacifism, on patriotic ground. Such people are not to be relied on in the hour of crisis as the world war amply proved.

I am most grateful to you for according me opportunity to give you my views in person.

Address to the Students' Disarmament Meeting

Preceding generations have presented us, in a highly developed science and mechanical knowledge, with most valuable gift which carries with it possibilities of making our life free and beautiful such as no previous generation has enjoyed. But this gift also brings with it dangers to our existence as great as any that have ever threatened it.

The destiny of civilised humanity depends more than ever on the moral forces it is capable of generating. Hence the task that confronts our age is certainly no easier than the tasks our immediate predecessors successfully performed.

The foodstuffs and other goods which the world needs can be produced in far fewer hours of work than formerly. But this has made the problem of the division

tion, from Jesus Christ to Goethe and Kant. Is it significant that such men have been universally regarded as leaders, in spite of the fact that their efforts would the course of human affairs were attended but small success?

I am convinced that the great men, those whose governments, even though in a restricted sphere, set above their fellows, are animated to an over-riding extent by the same ideals. But they have influence on the course of political events. It almost looks as if this domain, on which the fate of nations depends, had inevitably to be given over to chance and irresponsibility.

Political leaders or governments owe their position partly to force and partly to popular election. They cannot be regarded as representative of the best elements, morally and intellectually, in their respective nations. The intellectual elite have no direct influence on the policy of nations in these days, their lack of cohesion prevents them from taking a direct part in the solution of contemporary problems. Don't you think that a change might be brought about in this respect by a new association of people whose work and achievements up to date constitute a guarantee of their ability and purity of aim? This international association, whose members would need to keep in touch with each other by a constant interchange of opinions, might, by defining its attitude in the Press—responsibility always resting with the signatories on any given occasion—acquire a considerable and salutary moral influence over the settlement of political questions. Such an association would, of course, be a prey to all the evils which so often lead to degeneration in learned societies, dangers which are inseparably bound up with

the imperfection of human nature. But should not an effort in this direction be risked in spite of this? I look upon the attempt as nothing less than an imperative duty.

If an intellectual association of standing, such as I have described, could be formed, it would no doubt have to try to mobilise the religious organisations for the fight against war. It would give countenance to many whose good intentions are paralysed to-day by a melancholy resignation. Finally, I believe that an association formed of persons such as I have described, each highly esteemed in his own line, would be just the thing to give valuable moral support to those elements in the League of Nations which are really working for the great object for which that institution exists.

I had rather put these proposals to you than to anyone else in the world because you are least of all men the dupe of your desires and because your critical judgment is supported by a most earnest sense of responsibility.

Compulsory Service

From a letter

Instead of permission being given to Germany to introduce compulsory service it ought to be taken away from everybody else. In future none but mercenary armies should be permitted, the size and equipment of which should be discussed at Geneva. This would be better for France than to have to permit compulsory service in Germany. The fatal psychological effect of the military education of the people and the violation of the individual's rights which it involves would thus be avoided.

Moreover, it would be much easier for two countries which had agreed to compulsory arbitration for the settlement of all disputes arising out of their mutual relations to combine their military establishments of mercenaries into a single organisation with a mixed staff. This would mean a financial relief and increased security for both of them. Such a process of amalgamation might extend to larger and larger combinations, and finally lead to an "international police," which would be bound gradually to degenerate as international security increased.

Will you discuss this proposal with our friends by way of setting the ball rolling? Of course I do not in the least insist on this particular proposal. But I do think it essential that we should come forward with a positive programme; a merely negative policy is unlikely to produce any practical results.

Germany and France

Mutual trust and co-operation between France and Germany can only come about if the French demand for security against military attack is satisfied. But should France frame demands in accordance with this, such a step would certainly be taken very ill in Germany.

A procedure something like the following seems, however, to be possible. Let the German government of its own free will propose to the French that they should jointly make representations to the League of Nations that it should suggest to all member states to bind themselves to the following:—

- (1) To submit to every decision of the international court of arbitration.
- (2) To proceed with all its economic and military

force, in concert with the other members of the League, against any state which breaks the peace or resists an international decision made in the interests of world peace.

Arbitration

Systematic disarmament within a short period. This is only possible in combination with the guarantee of all for the security of each separate nation, based on a permanent court of arbitration independent of governments.

Unconditional obligation of all countries not merely to accept the decisions of the court of arbitration but also to give effect to them.

Separate courts of arbitration for Europe with Africa, America, and Asia (Australia to be apportioned to one of these). A joint court of arbitration for questions involving issues that cannot be settled within the limits of any one of these three regions.

The International of Science

At a sitting of the Academy during the War, at the time when national and political infatuation had reached its height, Enul Fischer spoke the following emphatic words:—"It's no use, Gentlemen, science is and remains international." The really great scientists have always known this and felt it passionately, even though in times of political confusion they may have remained isolated among their colleagues of inferior calibre. In every camp during the War this mass of voters betrayed their sacred trust. The international society of the academies was broken up. Congresses were and still

are held from which colleagues from ex-enemy countries are excluded. Political considerations, advanced with much solemnity, prevent the triumph of purely objective ways of thinking without which our great aims must necessarily be frustrated.

What can right-minded people, people who are proof against the emotional temptations of the moment, do to repair the damage? With the majority of intellectual workers still so excited, truly international congresses on the grand scale cannot yet be held. The psychological obstacles to the restoration of the international associations of scientific workers are still too formidable to be overcome by the minority whose ideas and feelings are of a more comprehensive kind. These last can aid in the great work of restoring the international societies to health by keeping in close touch with like-minded people all over the world, and resolutely championing the international cause in their own spheres. Success on a large scale will take time, but it will undoubtedly come. I cannot let this opportunity pass without paying a tribute to the way in which the desire to preserve the confraternity of the intellect has remained alive through all these difficult years in the breasts of a large number of our English colleagues especially.

The disposition of the individual is everywhere better than the official pronouncements. Right-minded people should bear this in mind and not allow themselves to be misled and get angry. *senatores boni viri, senatus autem bestia*.

If I am full of confident hope concerning the progress of international organisation in general, that feeling is based not so much on my confidence in the intelligence and high-mindedness of my fellows, but rather on the irresistible pressure of economic developments. And

since these depend largely on the work even of reactionary scientists, they too will help to create the international organisation against their wills.

The Institute for Intellectual Co-operation

During this year the leading politicians of Europe have for the first time drawn the logical conclusion from the truth that our portion of the globe can only regain its prosperity if the underground struggle between the traditional political units ceases. The political organisation of Europe must be strengthened, and a gradual attempt made to abolish tariff barriers. This great end cannot be achieved by treaties alone. People's minds must, above all, be prepared for it. We must try gradually to awaken in them a sense of solidarity which does not, as hitherto, stop at frontiers. It is with this in mind that the League of Nations has created the *Commission de co-opération intellectuelle*. This commission is to be an absolutely international and entirely non-political authority, whose business it is to put the intellectuals of all the nations, who were isolated by the war, into touch with each other. It is a difficult task; for it has, alas, to be admitted that—at least in the countries with which I am most closely acquainted—the artists and men of learning are governed by narrowly nationalist feelings to a far greater extent than the men of affairs.

Hitherto this commission has met twice a year. To make its efforts more effective, the French government has decided to create and maintain a permanent Institute for intellectual co-operation, which is just now to be opened. It is a generous act on the part of the French nation and deserves the thanks of all.

It is an easy and grateful task to rejoice and praise and say nothing about the things one regrets or disapproves of. But honesty alone can help our work forward, so I will not shrink from combining criticism with this greeting to the new-born child.

I have daily occasion for observing that the greatest obstacle which the work of our commission has to encounter is the lack of confidence in its political impartiality. Everything must be done to strengthen that confidence and everything avoided that might harm it.

When, therefore, the French government sets up and maintains an Institute out of public funds in Paris as a permanent organ of the Commission, with a Frenchman as its Director, the outside observer can hardly avoid the impression that French influence predominates in the Commission. This impression is further strengthened by the fact that a Frenchman has also been chairman of the Commission itself so far. Although the individuals in question are men of the highest reputation, liked and respected everywhere, nevertheless the impression remains.

Dixi et salvavi animam meam. I hope with all my heart that the new Institute by constant interaction with the Commission will succeed in promoting their common ends and winning the confidence and recognition of intellectual workers all over the world.

A Farewell

A letter to the German Secretary of the League
of Nations

Dear Herr Dufour-Feronce,

Your kind letter must not go unanswered, otherwise you may get a mistaken notion of my attitude. The grounds for my resolve to go to Geneva no more are as follows — Experience has, unhappily, taught me that the Commission, taken as a whole, stands for no serious determination to make real progress with the task of improving international relations. It looks to me far more like an embodiment of the principle *ut aliquid fieri videatur*. The Commission seems to me even worse in this respect than the League taken as a whole.

It is precisely because I desire to work with all my might for the establishment of an international arbitrating and regulative authority *superior to the state*, and because I have this object so very much at heart, that I feel compelled to leave the Commission.

The Commission has given its blessing to the oppression of the cultural minorities in all countries by causing a National Commission to be set up in each of them which is to form the only channel of communication between the intellectuals of a country and the Commission. It has thereby deliberately abandoned its function of giving moral support to the national minorities in their struggle against cultural oppression.

Further, the attitude of the Commission in the matter of combating the chauvinistic and militaristic tendencies of education in the various countries has been so lukewarm that no serious efforts in this fundamentally important sphere can be hoped for from it.

The Commission has invariably failed to give moral support to those individuals and associations who have thrown themselves without reserve into the business of working for an international order and against the military system

The Commission has never made any attempt to resist the appointment of members whom it knew to stand for tendencies the very reverse of those it is bound in duty to foster

I will not worry you with any further arguments, since you will understand my resolve well enough from these few hints. It is not my business to draw up an indictment but merely to explain my position. If I nourished any hope whatever I should act differently—of that you may be sure

The Question of Disarmament

The greatest obstacle to the success of the disarmament plan was the fact that people in general left out of account the chief difficulties of the problem. Most objects are gained by gradual steps: for example, the supersession of absolute monarchy by democracy. Here, however, we are concerned with an objective which cannot be reached step by step.

As long as the possibility of war remains, nations will insist on being as perfectly prepared militarily as they can, in order to emerge triumphant from the next war. It will also be impossible to avoid educating the youth in warlike traditions and cultivating narrow national vanity joined to the glorification of the warlike spirit, as long as people have to be prepared for occasions when such a spirit will be needed in the citizens for the purpose of war. To arm is to give one's voice and make

one's preparations not for peace but for war. Therefore people will not disarm step by step; they will disarm at one blow or not at all.

The accomplishment of such a far-reaching change in the life of nations presupposes a mighty moral effort, a deliberate departure from deeply ingrained tradition. Anyone who is not prepared to make the fate of his country in case of a dispute depend entirely on the decisions of an international court of arbitration and to enter into a treaty to this effect without reserve, is not really resolved to avoid war. It is a case of all or nothing.

It is undeniable that previous attempts to ensure peace have failed through aiming at inadequate compromises.

Disarmament and security are only to be had in combination. The one guarantee of security is an undertaking by all nations to give effect to the decisions of the international authority.

We stand, therefore, at the parting of the ways. Whether we find the way of peace or continue along the old road of brute force, so unworthy of our civilisation, depends on ourselves. On the one side the freedom of the individual and the security of society beckon to us, on the other slavery for the individual and the annihilation of our civilisation threaten us. Our fate will be according to our deserts.

The Disarmament Conference of 1932

I

May I begin with an article of political faith? It runs as follows:—The state is made for man, not man for the

state And in this respect science resembles the state These are old sayings, coined by men for whom human personality was the highest human good I should shrink from repeating them, were it not that they are for ever threatening to fall into oblivion, particularly in these days of organisation and mechanisation I regard it as the chief duty of the state to protect the individual and give him the opportunity to develop into a creative personality

That is to say, the state should be our servant and not we its slaves The state transgresses this commandment when it compels us by force to engage in military and war service, the more so since the object and the effect of this slavish service is to kill people belonging to other countries or interfere with their freedom of development We are only to make such sacrifices to the state as will promote the free development of individual human beings To any American all this may be a plantude, but not to any European Hence we may hope that the fight against war will find strong support among Americans

And now for the Disarmament Conference Ought one to laugh, weep or hope when one thinks of it? Imagine a city inhabited by fiery-tempered, dishonest and quarrelsome citizens The constant danger to life there is felt as a serious handicap which makes all healthy development impossible The magistrate desires to remedy this abominable state of affairs, although all his counsellors and the rest of the citizens insist on continuing to carry a dagger in their girdles After years of preparation the magistrate determines to compromise and raises the question, how long and how sharp the dagger is allowed to be which anyone may carry in his belt when he goes out As long as the cunning

citizens do not suppress knifing by legislation, the courts and the police, things go on in the old way, of course. A definition of the length and sharpness of the permitted dagger will only help the strongest and most turbulent and leave the weaker at their mercy. You will all understand the meaning of this parable. It is true that we have a League of Nations and a Court of Arbitration. But the League is not much more than a meeting-hall and the Court has no means of enforcing its decisions. These institutions provide no security for any country in case of an attack on it. If you bear this in mind, you will judge the attitude of the French, their refusal to disarm without security, less harshly than it is usually judged at present.

Unless we can agree to limit the sovereignty of the individual state by all binding ourselves to take joint action against any country which openly or secretly resists a judgment of the Court of Arbitration, we shall never get out of a state of universal anarchy and terror. No sleight of hand can reconcile the unlimited sovereignty of the individual country with security against attack. Will it need new disasters to induce the countries to undertake to enforce every decision of the recognised international court? The progress of events so far scarcely justifies us in hoping for anything better in the near future. But everyone who cares for civilisation and justice must exert all his strength to convince his fellows of the necessity for laying all countries under an international obligation of this kind.

It will be urged against this notion, not without a certain justification, that it over-estimates the efficacy of machinery, and neglects the psychological, or rather the moral, factor. Spiritual disarmament, people insist, must precede material disarmament. They say further,

and truly, that the greatest obstacle to international order is that monstrously exaggerated spirit of nationalism which also goes by the fair-sounding but misused name of patriotism. During the last century and a half this idol has acquired an uncanny and exceedingly pernicious power everywhere.

To estimate this objection at its proper worth, one must realise that a *reciprocal* relation exists between external machinery and internal states of mind. Not only does the machinery depend on traditional modes of feeling and owe its origin and its survival to them, but the existing machinery in its turn exercises a powerful influence on national modes of feeling.

The present deplorably high development of nationalism everywhere is, in my opinion, intimately connected with the institution of compulsory military service or, to call it by its less offensive name, national armies. A country which demands military service of its inhabitants is compelled to cultivate a nationalistic spirit in them, which provides the psychological foundation of military efficiency. Along with this religion it has to hold up its instrument, brute force, to the admiration of the youth in its schools.

The introduction of compulsory service is therefore, to my mind, the prime cause of the moral collapse of the white race, which seriously threatens not merely the survival of our civilisation but our very existence. This curse, along with great social blessings, started with the French Revolution, and before long dragged all the other nations in its train.

Therefore, those who desire to encourage the growth of an international spirit and to combat chauvinism must take their stand against compulsory service. Is the severe persecution to which conscientious objectors to

military service are subjected to-day a whit less disgraceful to the community than those to which the martyrs of religion were exposed in former centuries? Can you, as the Kellogg Pact does, condemn war and at the same time leave the individual to the tender mercies of the war machine in each country?

If, in view of the Disarmament Conference, we are not to restrict ourselves to the technical problems of organisation involved but also to tackle the psychological question more directly from educational motives, we must try on international lines to invent some legal way by which the individual can refuse to serve in the army. Such a regulation would undoubtedly produce a great moral effect.

This is my position in a nutshell — Mere agreements to limit armaments furnish no sort of security. Compulsory arbitration must be supported by an executive force, guaranteed by all the participating countries, which is ready to proceed against the disturber of the peace with economic and military sanctions. Compulsory service, as the bulwark of unhealthy nationalism, must be combated, most important of all, conscientious objectors must be protected on an international basis.

Finally, I would draw your attention to a book, *War again to-morrow*, by Ludwig Bauer, which discusses the issues here involved in an acute and unprejudiced manner and with great psychological insight.

II

The benefits that the inventive genius of man has conferred on us in the last hundred years could make life happy and care-free, if organisation had been able to keep pace with technical progress. As it is, these

hard-won achievements in the hands of our generation are like a razor in the hands of a child of three. The possession of marvellous means of production has brought care and hunger instead of freedom.

The results of technical progress are most baleful where they furnish means for the destruction of human life and the hard-won fruits of toil, as we of the older generation experienced to our horror in the Great War. More dreadful even than the destruction, in my opinion, is the humiliating slavery into which war plunges the individual. Is it not a terrible thing to be forced by the community to do things which every individual regards as abominable crimes? Only a few had the moral greatness to resist, them I regard as the real heroes of the Great War.

There is one ray of hope. I believe that the responsible leaders of the nations do, in the main, honestly desire to abolish war. The resistance to this essential step forward comes from those unfortunate national traditions which are handed on like a hereditary disease from generation to generation through the workings of the educational system. The principal vehicle of this tradition is military training and its glorification, and, equally, that portion of the Press which is controlled by heavy industry and the soldiers. Without disarmament there can be no lasting peace. Conversely, the continuation of military preparations on the present scale will inevitably lead to new catastrophes.

That is why the Disarmament Conference of 1932 will decide the fate of this generation and the next. When one thinks how pitiable, taken as a whole, have been the results of former conferences, it becomes clear that it is the duty of all intelligent and responsible people to exert their full powers to remind public opinion

America and the Disarmament Conference

The Americans of to-day are filled with the cares arising out of economic conditions in their own country. The efforts of their responsible leaders are directed primarily to remedying the serious unemployment at home. The sense of being involved in the destiny of the rest of the world, and in particular of the mother country of Europe, is even less strong than in normal times.

But the free play of economic forces will not by itself automatically overcome these difficulties. Regulative measures by the community are needed to bring about a sound distribution of labour and consumption-goods among mankind; without them even the people of the richest country suffocate. The fact is that since the amount of work needed to supply everybody's needs has been reduced through the improvement of technical methods, the free play of economic forces no longer produces a state of affairs in which all the available labour can find employment. Deliberate regulation and organisation are becoming necessary to make the results of technical progress beneficial to all.

If the economic situation cannot be cleared up without systematic regulation, how much more necessary is such regulation for dealing with the problems of international politics! Few people still cling to the notion that acts of violence in the shape of wars are either advantageous or worthy of humanity as a method of solving international problems. But they are not logical enough to make vigorous efforts on behalf of the measures which might prevent war, that savage and unworthy relic of the age of barbarism. It requires some power of reflection to see the issue clearly and a

certain courage to serve this great cause resolutely and effectively

Anybody who really wants to abolish war must resolutely declare himself in favour of his own country's resigning a portion of its sovereignty in favour of international institutions he must be ready to make his own country amenable, in case of a dispute, to the award of an international court He must in the most uncompromising fashion support disarmament all round, which is actually envisaged in the unfortunate Treaty of Versailles, unless military and aggressively patriotic education is abolished, we can hope for no progress

No event of the last few years reflects such disgrace on the leading civilised countries of the world as the failure of all disarmament conferences so far, for this failure is due not only to the intrigues of ambitious and unscrupulous politicians but also to the indifference and slackness of the public in all countries Unless this is changed we shall destroy all the really valuable achievements of our predecessors

I believe that the American nation is only imperfectly aware of the responsibility which rests with it in this matter People in America no doubt think as follows — "Let Europe go to the dogs, if it is destroyed by the quarrelsomeness and wickedness of its inhabitants The good seed of our Wilson has produced a mighty poor crop in the stony ground of Europe We are strong and safe and in no hurry to mix ourselves up in other people's affairs"

Such an attitude is at once base and short-sighted America is partly to blame for the difficulties of Europe By ruthlessly pressing her claims she is hastening the economic and therewith the moral collapse of Europe, she has helped to Balkanise Europe and therefore shares

the responsibility for the breakdown of political morality and the growth of that spirit of revenge which feeds on despair. This spirit will not stop short of the gates of America—I had almost said, has not stopped short. Look around, and look forward.

The truth can be briefly stated:—The Disarmament Conference comes as a final chance, to you no less than to us, of preserving the best that civilised humanity has produced. And it is on you, as the strongest and comparatively soundest among us, that the eyes and hopes of all are focussed.

Active Pacifism

I consider myself lucky in witnessing the great peace demonstration organised by the Flemish people. To all concerned in it I feel impelled to call out in the name of men of good will with a care for the future: "In this hour of opened eyes and awakening conscience we feel ourselves united with you by the deepest ties."

We must not conceal from ourselves that an improvement in the present depressing situation is impossible without a severe struggle; for the handful of those who are really determined to do something is minute in comparison with the mass of the lukewarm and the misguided. And those who have an interest in keeping the machinery of war going are a very powerful body; they will stop at nothing to make public opinion subservient to their murderous ends.

It looks as if the ruling statesmen of to-day were really trying to secure permanent peace. But the ceaseless piling-up of armaments shows only too clearly that they are unequal to coping with the hostile forces which are preparing for war. In my opinion, deliver-

ance can only come from the peoples themselves. If they wish to avoid the degrading slavery of war-service, they must declare with no uncertain voice for complete disarmament. As long as armies exist, any serious quarrel will lead to war. A pacifism which does not actually try to prevent the nations from arming is and must remain impotent.

May the conscience and the common sense of the peoples be awakened, so that we may reach a new stage in the life of nations, where people will look back on war as an incomprehensible aberration of their forefathers!

Letter to a friend of Peace

It has come to my ears that in your great-heartedness you are quietly accomplishing a splendid work, impelled by solicitude for humanity and its fate. Small is the number of them that see with their own eyes and feel with their own hearts. But it is their strength that will decide whether the human race must relapse into that hopeless condition which a blind multitude appears to-day to regard as the ideal.

O that the nations might see, before it is too late, how much of their self-determination they have got to sacrifice in order to avoid the struggle of all against all! The power of conscience and the international spirit has proved itself inadequate. At present it is being so weak as to tolerate parleying with the worst enemies of civilisation. There is a kind of conciliation which is a crime against humanity, and it passes for political wisdom.

We cannot despair of humanity, since we are ourselves human beings. And it is a comfort that there still

exist individuals like yourself, whom one knows to be alive and undismayed.

Another ditto

Dear friend and spiritual brother,

To be quite frank, a declaration like the one before me in a country which submits to conscription in peacetime seems to me valueless. What you must fight for is liberation from universal military service. Verily the French nation has had to pay heavily for the victory of 1918; for that victory has been largely responsible for holding it down in the most degrading of all forms of slavery. Let your efforts in this struggle be unceasing. You have a mighty ally in the German reactionaries and militarists. If France clings to universal military service, it will be impossible in the long run to prevent its introduction into Germany. For the demand of the Germans for equal rights will succeed in the end; and then there will be two German military slaves to every French one, which would certainly not be in the interests of France.

Only if we succeed in abolishing compulsory service altogether will it be possible to educate the youth in the spirit of reconciliation, joy in life and love towards all living creatures.

I believe that a refusal on conscientious grounds to serve in the army when called up, if carried out by 50,000 men at the same moment, would be irresistible. The individual can accomplish little here, nor can one wish to see the best among us devoted to destruction through the machinery behind which stand the three great powers of stupidity, fear, and greed.

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A third ditto

Dear Sir,

The point with which you deal in your letter is one of prime importance. The armament industry is, as you say, one of the greatest dangers that beset mankind. It is the hidden evil power behind the nationalism which is rampant everywhere.

Possibly something might be gained by nationalisation. But it is extremely hard to determine exactly what industries should be included. Should the aircraft industry? And how much of the metal industry and the chemical industry?

As regards the munitions industry and the export of war material, the League of Nations has busied itself for years with efforts to get this horrible traffic controlled—with what little success, we all know. Last year I asked a well-known American diplomat why Japan was not forced by a commercial boycott to desist from her policy of force. "Our commercial interests are too strong," was the answer. How can one help people who rest satisfied with a statement like that?

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Women and War

In my opinion, the patriotic women ought to be sent to the front in the next war instead of the men. It would at least be a novelty in this dreary sphere of infinite confusion, and besides—why should not such heroic feelings on the part of the fair sex find a more picturesque outlet than in attacks on a defenceless civilian?

Thoughts on the World Economic Crisis

If there is one thing that can give a layman in the sphere of economics the courage to express an opinion on the nature of the alarming economic difficulties of the present day, it is the hopeless confusion of opinions among the experts. What I have to say is nothing new and does not pretend to be anything more than the opinion of an independent and honest man who, unburdened by class or national prejudices, desires nothing but the good of humanity and the most harmonious possible scheme of human existence. If in what follows I write as if I were clear about certain things and sure of the truth of what I am saying, this is merely done for the sake of an easier mode of expression, it does not proceed from unwarranted self-confidence or a belief in the infallibility of my somewhat simple intellectual conception of problems which are in reality uncommonly complex.

As I see it, this crisis differs in character from past crises in that it is based on an entirely new set of conditions, due to rapid progress in methods of production

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You believe that a word from me would suffice to get something done in this sphere? What an illusion! People flatter me as long as I do not get in their way. But if I direct my efforts towards objects which do not suit them, they immediately turn to abuse and calumny in defence of their interests. And the onlookers mostly keep out of the light, the cowards! Have you ever tested the civil courage of your countrymen? The silently accepted motto is "Leave it alone and don't speak of it." You may be sure that I shall do everything in my power along the lines you indi-

cate, but nothing can be achieved as directly as you think.

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If there is one thing that can give a layman in the sphere of economics the courage to express an opinion on the nature of the alarming economic difficulties of the present day, it is the hopeless confusion of opinions among the experts. What I have to say is nothing new and does not pretend to be anything more than the opinion of an independent and honest man who, unburdened by class or national prejudices, desires nothing but the good of humanity and the most harmonious possible scheme of human existence. If in what follows I write as if I were clear about certain things and sure of the truth of what I am saying, this is merely done for the sake of an easier mode of expression; it does not proceed from unwarranted self-confidence or a belief in the infallibility of my somewhat simple intellectual conception of problems which are in reality uncommonly complex.

As I see it, this crisis differs in character from past crises in that it is based on an entirely new set of conditions, due to rapid progress in methods of production.

Only a fraction of the available human labour in the world is needed for the production of the total amount of consumption-goods necessary to life. Under a completely free economic system this fact is bound to lead to unemployment. For reasons which I do not propose to analyse here, the majority of people are compelled to work for the minimum wage on which life can be supported. If two factories produce the same sort of goods, other things being equal, that one will be able to produce them more cheaply which employs less workmen—i.e., makes the individual worker work as long and as hard as human nature permits. From this it follows inevitably that, with methods of production what they are to-day, only a portion of the available labour can be used. While unreasonable demands are made on this portion, the remainder is automatically excluded from the process of production. This leads to a fall in sales and profits. Businesses go smash, which further increases unemployment and diminishes confidence in industrial concerns and therewith public participation in these mediating banks, finally the banks become insolvent through the sudden withdrawal of deposits and the wheels of industry therewith come to a complete standstill.

The crisis has also been attributed to other causes which we will now consider.

(1) *Over-production*. We have to distinguish between two things here—real over-production and apparent over-production. By real over-production I mean a production so great that it exceeds the demand. This may perhaps apply to motor-cars and wheat in the United States at the present moment, although even that is doubtful. By "over-production" people usually

mean a condition of things in which more of one particular article is produced than can, in existing circumstances, be sold, in spite of a shortage of consumption-goods among consumers. This condition of things I call apparent over-production. In this case it is not the demand that is lacking but the consumers' purchasing-power. Such apparent over-production is only another word for a crisis and therefore cannot serve as an explanation of the latter, hence people who try to make over-production responsible for the crisis are merely juggling with words.

(2) *Reparations* The obligation to pay reparations lies heavy on the debtor nations and their industries, compels them to go in for dumping and so harms the creditor nations too. This is beyond dispute. But the appearance of the crisis in the United States, in spite of the high tariff-wall protecting them, proves that this cannot be the principal cause of the world crisis. The shortage of gold in the debtor countries due to reparations can at most serve as an argument for putting an end to these payments, it cannot be dragged in as an explanation of the world crisis.

(3) *Erection of new tariff-walls* Increase in the unproductive burden of armaments. Political insecurity owing to latent danger of war. All these things add considerably to the troubles of Europe but do not materially affect America. The appearance of the crisis in America shows that they cannot be its principal causes.

(4) *The dropping-out of the two powers, China and Russia* This blow to world trade also does not touch America very nearly and therefore cannot be a principal cause of the crisis.

(5) *The economic rise of the lower classes since the War*
 Thus, supposing it to be a reality, could only produce a scarcity of goods, not an excessive supply

I will not weary the reader by enumerating further contentions which do not seem to me to get to the heart of the matter. Of one thing I feel certain this same technical progress which, in itself, might relieve mankind of a great part of the labour necessary to its subsistence, is the main cause of our present troubles. Hence there are those who would in all seriousness forbid the introduction of technical improvements. This is obviously absurd. But how can we find a more rational way out of our dilemma?

If we could somehow manage to prevent the purchasing-power of the masses, measured in terms of goods, from sinking below a certain minimum, stoppages in the industrial cycle such as we are experiencing to-day would be rendered impossible.

The logically simplest but also most daring method of achieving this is a completely planned economy, in which consumption-goods are produced and distributed by the community. That, in essentials, is what is being attempted in Russia to-day. Much will depend on what results this mighty experiment produces. To hazard a prophecy here would be presumption. Can goods be produced as economically under such a system as under one which leaves more freedom to individual enterprise? Can this system maintain itself at all without the terror that has so far accompanied it, which none of us "westerners" would care to let himself in for? Does not such a rigid, centralised system tend towards protection and hostility to advantageous innovations? We must take care, however, not to allow these suspicions to become pre-

judices which prevent us from forming an objective judgment.

My personal opinion is that those methods are preferable which respect existing traditions and habits so far as that is in any way compatible with the end in view. Nor do I believe that a sudden transference of the control of industry to the hands of the public would be beneficial from the point of view of production; private enterprise should be left its sphere of activity, in so far as it has not already been eliminated by industry itself in the form of cartelisation.

There are, however, two respects in which this economic freedom ought to be limited. In each branch of industry the number of working hours per week ought so to be reduced by law that unemployment is systematically abolished. At the same time minimum wages must be fixed in such a way that the purchasing power of the workers keeps pace with production.

Further, in those industries which have become monopolistic in character through organisation on the part of the producers, prices must be controlled by the state in order to keep the creation of new capital within reasonable bounds and prevent the artificial strangling of production and consumption.

In this way it might perhaps be possible to establish a proper balance between production and consumption without too great a limitation of free enterprise and at the same time to stop the intolerable tyranny of the owners of the means of production (land, machinery) over the wage-earners, in the widest sense of the term.

Culture and Prosperity

If one would estimate the damage done by the great political catastrophe to the development of human civilisation, one must remember that culture in its higher forms is a delicate plant which depends on a complicated set of conditions and is wont to flourish only in a few places at any given time. For it to blossom there is needed, first of all, a certain degree of prosperity, which enables a fraction of the population to work at things not directly necessary to the maintenance of life, secondly, a moral tradition of respect for cultural values and achievements, in virtue of which this class is provided with the means of living by the other classes, those who provide the immediate necessities of life.

During the past century Germany has been one of the countries in which both conditions were fulfilled. The prosperity was, taken as a whole, modest but sufficient, the tradition of respect for culture vigorous. On this basis the German nation has brought forth fruits of culture which form an integral part of the development of the modern world. The tradition, in the main, still stands, the prosperity is gone. The industries of the country have been cut off almost completely from the sources of raw materials on which the existence of the industrial part of the population was based. The surplus necessary to support the intellectual worker has suddenly ceased to exist. With it the tradition which depends on it will inevitably collapse also, and a fruitful nursery of culture turn to wilderness.

The human race, in so far as it sets a value on culture, has an interest in preventing such impoverishment.

It will give what help it can in the immediate crisis and reawaken that higher community of feeling, now thrust into the background by national egotism, for which human values have a validity independent of politics and frontiers. It will then procure for every nation conditions of work under which it can exist and under which it can bring forth fruits of culture.

Production and Purchasing Power

I do not believe that the remedy for our present difficulties lies in a knowledge of productive capacity and consumption, because this knowledge is likely, in the main, to come too late. Moreover the trouble in Germany seems to me to be not hypertrophy of the machinery of production but deficient purchasing power in a large section of the population, which has been cast out of the productive process through rationalisation.

The gold standard has, in my opinion, the serious disadvantage that a shortage in the supply of gold automatically leads to a contraction of credit and also of the amount of currency in circulation, to which contraction prices and wages cannot adjust themselves sufficiently quickly. The natural remedies for our troubles are, in my opinion, as follows —

(1) A statutory reduction of working hours, graduated for each department of industry, in order to get rid of unemployment, combined with the fixing of minimum wages for the purpose of adjusting the purchasing-power of the masses to the amount of goods available.

(2) Control of the amount of money in circulation and of the volume of credit in such a way as to keep

the price-level steady, all special protection being abolished

(3) Statutory limitation of prices for such articles as have been practically withdrawn from free competition by monopolies or the formation of cartels

Production and Work

An answer to Cederstrom

Dear Herr Cederstrom,

Thank you for sending me your proposals, which interest me very much. Having myself given so much thought to this subject I feel that it is right that I should give you my perfectly frank opinion on them.

The fundamental trouble seems to me to be the almost unlimited freedom of the labour market combined with extraordinary progress in the methods of production. To satisfy the needs of the world to-day nothing like all the available labour is wanted. The result is unemployment and excessive competition among the workers, both of which reduce purchasing power and put the whole economic system intolerably out of gear.

I know Liberal economists maintain that every economy in labour is counterbalanced by an increase in demand. But, to begin with, I don't believe it, and even if it were true, the above-mentioned factors would always operate to force the standard of living of a large portion of the human race down to an unnaturally low level.

I also share your conviction that steps absolutely must be taken to make it possible and necessary for the younger people to take part in the productive process

Further, that the older people ought to be excluded from certain sorts of work (which I call "unqualified" work), receiving instead a certain income, as having by that time done enough work of a kind accepted by society as productive.

I too am in favour of abolishing large cities, but not of settling people of a particular type, e.g., old people, in particular towns. Frankly, the idea strikes me as horrible. I am also of opinion that fluctuations in the value of money must be avoided, by substituting for the gold standard a standard based on certain classes of goods selected according to the conditions of consumption—as Keynes, if I am not mistaken, long ago proposed. With the introduction of this system one might consent to a certain amount of "inflation," as compared with the present monetary situation, if one could believe that the state would really make a rational use of the windfall thus accruing to it.

The weaknesses of your plan lie, so it seems to me, in the sphere of psychology, or rather, in your neglect of it. It is no accident that capitalism has brought with it progress not merely in production but also in knowledge. Egoism and competition are, alas, stronger forces than public spirit and sense of duty. In Russia, they say, it is impossible to get a decent piece of bread. . . . Perhaps I am over-pessimistic concerning state and other forms of communal enterprise, but I expect little good from them. Bureaucracy is the death of all sound work. I have seen and experienced too many dreadful warnings, even in comparatively model Switzerland.

I am inclined to the view that the state can only be of real use to industry as a limiting and regulative force. It must see to it that competition among the workers

is kept within healthy limits, that all children are given a chance to develop soundly, and that wages are high enough for the goods produced to be consumed. But it can exert a decisive influence through its regulative function if—and there again you are right—its measures are framed in an objective spirit by independent experts.

I would like to write to you at greater length, but cannot find the time.

Minorities

It seems to be a universal fact that minorities—especially when the individuals composing them are distinguished by physical peculiarities—are treated by the majorities among whom they live as an inferior order of beings. The tragedy of such a fate lies not merely in the unfair treatment to which these minorities are automatically subjected in social and economic matters, but also in the fact that under the suggestive influence of the majority most of the victims themselves succumb to the same prejudice and regard their brethren as inferior beings. This second and greater part of the evil can be overcome by closer combination and by deliberate education of the minority, whose spiritual liberation can thus be accomplished.

The efforts of the American negroes in this direction are deserving of all commendation and assistance.

Observations on the Present Situation in Europe

The distinguishing feature of the present political situation of the world, and in particular of Europe, seems to me to be this, that political development

PART III

GERMANY 1933

GERMANY 1933

Manifesto

AS long as I have any choice, I will only stay in a country where political liberty, toleration, and equality of all citizens before the law are the rule. Political liberty implies liberty to express one's political views orally and in writing, toleration, respect for any and every individual opinion.

These conditions do not obtain in Germany at the present time. Those who have done most for the cause of international understanding, among them some of the leading artists, are being persecuted there.

Any social organism can become psychically dis-tempered just as any individual can, especially in times of difficulty. Nations usually survive these distempers. I hope that healthy conditions will soon supervene in Germany, and that in future her great men like Kant and Goethe will not merely be commemorated from time to time but that the principles which they inculcated will also prevail in public life and in the general consciousness.

March, 1933

Correspondence with the Prussian Academy of Sciences

The following correspondence is here published for the first time in its authentic and complete form. The version published in German newspapers was for the most part incorrect, important sentences being omitted.

The Academy's declaration of April 1st, 1933, against Einstein

THE WORLD AS I SEE IT

The Prussian Academy of Sciences heard with indignation from the newspapers of Albert Einstein's participation in atrocity-mongering in France and America. It immediately demanded an explanation. In the meantime Einstein has announced his withdrawal from the Academy, giving as his reason that he cannot continue to serve the Prussian state under its present government. Being a Swiss citizen he also, it seems, intends to resign the Prussian nationality which he acquired in 1913 simply by becoming a full member of the Academy.

The Prussian Academy of Sciences is particularly distressed by Einstein's activities as an agitator in *foreign countries, as it and its members have always* felt themselves bound by the closest ties to the Prussian state and, while abstaining strictly from all political partisanship, have always stressed and remained faithful to the national idea. It has therefore, no reason to regret Einstein's withdrawal.

Prof Dr Ernst Heymann
Perpetual Secretary

Le Coq near Ostende April 5th 1933

To the Prussian Academy of Sciences

I have received information from a thoroughly reliable source that the Academy of Sciences has spoken in an official statement of Einstein's participation in atrocity-mongering in America and France.

I hereby declare that I have never taken any part in atrocity mongering and I must add that I have seen nothing of any such mongering anywhere. In general people have contented themselves with reproducing and commenting on the official statements and orders

of responsible members of the German government, together with the programme for the annihilation of the German Jews by economic methods

The statements I have issued to the Press were concerned with my intention to resign my position in the Academy and renounce my Prussian citizenship, I gave as my reason for these steps that I did not wish to live in a country where the individual does not enjoy equality before the law and freedom to say and teach what he likes

Further, I described the present state of affairs in Germany as a state of psychic distemper in the masses and also made some remarks about its causes

In a written document which I allowed the International League for combating Anti-Semitism to make use of for the purpose of enlisting support and which was not intended for the Press at all, I also called upon all sensible people, who are still faithful to the ideals of a civilisation in peril, to do their utmost to prevent this mass-psychosis, which is exhibiting itself in such terrible symptoms in Germany to-day, from spreading further

It would have been an easy matter for the Academy to get hold of a correct version of my words before issuing the sort of statement about me that it has. The German Press has reproduced a deliberately distorted version of my words, as indeed was only to be expected with the Press muzzled as it is to-day

I am ready to stand by every word I have published. In return, I expect the Academy to communicate this statement of mine to its members and also to the German public before which I have been slandered, especially as it has itself had a hand in slandering me before that public

The Academy's answer of April 11th, 1933

The Academy would like to point out that its statement of April 1st, 1933, was based not merely on German but principally on foreign, particularly French and Belgian, newspaper reports which Herr Einstein has not contradicted; in addition, it had before it his much-canvassed statement to the League for combating anti-Semitism, in which he deplors Germany's relapse into the barbarism of long-passed ages. Moreover, the Academy has reason to know that Herr Einstein, who according to his own statement has taken no part in atrocity-mongering, has at least done nothing to counteract unjust suspicions and slanders, which, in the opinion of the Academy, it was his duty as one of its senior members to do. Instead of that Herr Einstein has made statements, and in foreign countries at that, such as, coming from a man of world-wide reputation, were bound to be exploited and abused by the enemies not merely of the present German government but of the whole German people.

For the Prussian Academy of Sciences,

(Signed) H. von Ficker,

E. Heymann,

Perpetual Secretaries.

Berlin, April 7th, 1933.

The Prussian Academy of Sciences,

Professor Albert Einstein, Leyden,

c/o Prof Ehrenfest, Witte Rosenstr.

Dear Sir,

As the present Principal Secretary of the Prussian Academy I beg to acknowledge the receipt of your

communication dated March 28th announcing your resignation of your membership of the Academy. The Academy took cognizance of your resignation in its plenary session of March 30th, 1933.

While the Academy profoundly regrets the turn events have taken, this regret is inspired by the thought that a man of the highest scientific authority, whom many years of work among Germans and many years of membership of our society must have made familiar with the German character and German habits of thought, should have chosen this moment to associate himself with a body of people abroad who—partly no doubt through ignorance of actual conditions and events—have done much damage to our German people by disseminating erroneous views and unfounded rumours. We had confidently expected that one who had belonged to our Academy for so long would have ranged himself, irrespective of his own political sympathies, on the side of the defenders of our nation against the flood of lies which has been let loose upon it. In these days of mud-slinging, some of it vile, some of it ridiculous, a good word for the German people from you in particular might have produced a great effect, especially abroad. Instead of which your testimony has served as a handle to the enemies not merely of the present Government but of the German people. This has come as a bitter and grievous disappointment to us, which would no doubt have led inevitably to a parting of the ways even if we had not received your resignation.

Yours faithfully,

(signed) von Ficker.

Le Coq-sur-Mer, Belgium,
April 12th, 1933

To the Prussian Academy of Sciences, Berlin

I have received your communication of the 7th instant and deeply deplore the mental attitude displayed in it

As regards the fact, I can only reply as follows — What you say about my behaviour is, at bottom, merely another form of the statement you have already published, in which you accuse me of having taken part in atrocity-mongering against the German nation. I have already, in my last letter, characterised this accusation as slanderous.

You have also remarked that a "good word" on my part for "the German people" would have produced a great effect abroad. To this I must reply that such a testimony as you suggest would have been equivalent to a repudiation of all those notions of justice and liberty for which I have all my life stood. Such a testimony would not be, as you put it, a good word for the German nation, on the contrary, it would only have helped the cause of those who are seeking to undermine the ideas and principles which have won for the German nation a place of honour in the civilised world. By giving such a testimony in the present circumstances I should have been contributing, even if only indirectly, to the barbarisation of manners and the destruction of all existing cultural values.

It was for this reason that I felt compelled to resign from the Academy, and your letter only shows me how right I was to do so.

Munich, *April 8th, 1933*

From the Bavarian Academy of Sciences
to Professor Albert Einstein.

Sir,

In your letter to the Prussian Academy of Sciences you have given the present state of affairs in Germany as the reason for your resignation. The Bavarian Academy of Sciences, which some years ago elected you a corresponding member, is also a German Academy, closely allied to the Prussian and other German Academies; hence your withdrawal from the Prussian Academy of Sciences is bound to affect your relations with our Academy.

We must therefore ask you how you envisage your relations with our Academy after what has passed between yourself and the Prussian Academy.

The President of the Bavarian Academy of Sciences.

Le Coq-sur-Mer, April 21st, 1933

To the Bavarian Academy of Sciences, Munich.

I have given it as the reason for my resignation from the Prussian Academy that in the present circumstances I have no wish either to be a German citizen or to remain in a position of quasi-dependence on the Prussian Ministry of Education.

These reasons would not, in themselves, involve the severing of my relations with the Bavarian Academy. If I nevertheless desire my name to be removed from the list of members, it is for a different reason.

The primary duty of an Academy is to encourage and protect the scientific life of a country. The learned

societies of Germany have, however—to the best of knowledge—stood by and said nothing while a not inconsiderable proportion of German savants and students, and also of professional men of university education, have been deprived of all chance of getting employment or earning their livings in Germany. I would rather not belong to any society which behaves in such a manner, even if it does so under external pressure.

A Reply

The following lines are Einstein's answer to an invitation to associate himself with a French manifesto against Anti-Semitism in Germany.

I have considered this most important proposal, which has a bearing on several things that I have nearly at heart, carefully from every angle. As a result I have come to the conclusion that I cannot take a personal part in this extremely important affair, for two reasons —

In the first place I am, after all, still a German citizen, and in the second I am a Jew. As regards the first point I must add that I have worked in German institutions and have always been treated with full confidence in Germany. However deeply I may regret the things that are being done there, however strongly I am bound to condemn the terrible mistakes that are being made with the approval of the government, it is impossible for me to take part personally in an enterprise set on foot by responsible members of a foreign government. In order that you may appreciate this fully, suppose that a French citizen in a more or less analogous situation had got up a protest against the French government's action in conjunction with

prominent German statesmen. Even if you fully admitted that the protest was amply warranted by the facts, you would still, I expect, regard the behaviour of your fellow-citizen as an act of treachery. If Zola had felt it necessary to leave France at the time of the Dreyfus case, he would still certainly not have associated himself with a protest by German official personages, however much he might have approved of their action. He would have confined himself to—blushing for his countrymen. In the second place, a protest against injustice and violence is incomparably more valuable if it comes entirely from people who have been prompted to it purely by sentiments of humanity and a love of justice. This cannot be said of a man like me, a Jew who regards other Jews as his brothers. For him, an injustice done to the Jews is the same as an injustice done to himself. He must not be the judge in his own case, but wait for the judgment of impartial outsiders.

These are my reasons. But I should like to add that I have always honoured and admired that highly developed sense of justice which is one of the noblest features of the French tradition.

PART IV

THE JEWS

THE JEWS

Jewish Ideals

THE pursuit of knowledge for its own sake, an almost fanatical love of justice, and the desire for personal independence—these are the features of the Jewish tradition which make me thank my stars that I belong to it

Those who are raging to-day against the ideals of reason and individual liberty and are trying to establish a spiritless state-slavery by brute force rightly see in us their irreconcilable foes. History has given us a difficult row to hoe, but so long as we remain devoted servants of truth, justice and liberty, we shall continue not merely to survive as the oldest of living peoples, but by creative work to bring forth fruits which contribute to the ennoblement of the human race, as heretofore

Is there a Jewish point of view ?

In the philosophical sense there is, in my opinion, no specifically Jewish outlook. Judaism seems to me to be concerned almost exclusively with the moral attitude in life and to life. I look upon it as the essence of an attitude to life which is incarnate in the Jewish people rather than the essence of the laws laid down in the Thora and interpreted in the Talmud. To me, the Thora and the Talmud are merely the most important evidence for the manner in which the Jewish conception of life held sway in earlier times

The essence of that conception seems to me to lie in an affirmative attitude ~~to~~ the life of all creation. The life of the individual ~~only~~ has meaning in so far as it aids in making the life of every living thing nobler and more beautiful. Life is sacred—that is to say, it is the supreme value, to which all other values are subordinate. The hallowing of the supra-individual life brings in its train a reverence for everything spiritual—a particularly characteristic feature of the Jewish tradition.

Judaism is not a creed: the Jewish God is simply a negation of superstition, an imaginary result of its elimination. It is also an attempt to base the moral law on fear, a regrettable and discreditable attempt. Yet it seems to me that the strong moral tradition of the Jewish nation has to a large extent shaken itself free from this fear. It is clear also that "serving God" was equated with "serving the living." The best of the Jewish people, especially the Prophets and Jesus contended tirelessly for this.

Judaism is thus no transcendental religion, it is concerned with life as we live it and can up to a point grasp it, and nothing else. It seems to me, therefore, doubtful whether it can be called a religion in the accepted sense of the word, particularly as no "faith" but the sanctification of life in a supra-personal sense is demanded of the Jew.

But the Jewish tradition also contains something else, something which finds splendid expression in many of the Psalms: namely, a sort of intoxicated joy and amazement at the beauty and grandeur of this world, of which man can just form a faint notion. It is the feeling from which true scientific research draws its spiritual sustenance, but which also seems to

find expression in the song of birds To tack this on to the idea of God seems mere childish absurdity

Is what I have described a distinguishing mark of Judaism? Is it to be found anywhere else under another name? In its pure form, nowhere, not even in Judaism, where the pure doctrine is obscured by much worship of the letter Yet Judaism seems to me one of its purest and most vigorous manifestations This applies particularly to the fundamental principle of the sanctification of life

It is characteristic that the animals were expressly included in the command to keep holy the Sabbath day, so strong was the feeling that the ideal demands the solidarity of all living things The insistence on the solidarity of all human beings finds still stronger expression, and it is no mere chance that the demands of Socialism were for the most part first raised by Jews

How strongly developed this sense of the sanctity of life is in the Jewish people is admirably illustrated by a little remark which Walter Rathenau once made to me in conversation "When a Jew says that he's going hunting to amuse himself, he lies" The Jewish sense of the sanctity of life could not be more simply expressed

Jewish Youth

An Answer to a Questionnaire

It is important that the young should be induced to take an interest in Jewish questions and difficulties, and you deserve gratitude for devoting yourself to this task in your paper This is of moment not merely for the destiny of the Jews, whose welfare depends on their sticking together and helping each other, but, over and

above that, for the cultivation of the international spirit, which is in danger everywhere to-day from a narrow-minded nationalism. Here, since the days of the Prophets, one of the fairest fields of activity has lain open to our nation, scattered as it is over the earth and only united by a common tradition.

Addresses on Reconstruction in Palestine

I

Ten years ago, when I first had the pleasure of addressing you on behalf of the Zionist cause, almost all our hopes were still fixed on the future. To-day we can look back on these ten years with joy, for in that time the united energies of the Jewish people have accomplished a splendid piece of successful constructive work in Palestine, which certainly exceeds anything that we dared to hope then.

We have also successfully stood the severe test to which the events of the last few years have subjected us. Ceaseless work, supported by a noble purpose is leading slowly but surely to success. The latest pronouncements of the British government indicate a return to a juster judgment of our case, this we recognise with gratitude.

But we must never forget what this crisis has taught us—namely, that the establishment of satisfactory relations between the Jews and the Arabs is not England's affair but ours. We—that is to say, the Arabs and ourselves—have got to agree on the main outlines of an advantageous partnership which shall satisfy the needs of both nations. A just solution of this problem and one worthy of both nations is an end no

less important and no less worthy of our efforts than the promotion of the work of construction itself. Remember that Switzerland represents a higher stage of political development than any national state, precisely because of the greater political problems which had to be solved before a stable community could be built up out of groups of different nationality.

Much remains to be done, but one at least of Herzl's aims has already been realised: its task in Palestine has given the Jewish people an astonishing degree of solidarity and the optimism without which no organism can lead a healthy life.

Anything we may do for the common purpose is done not merely for our brothers in Palestine but for the well-being and honour of the whole Jewish people.

II

We are assembled to-day for the purpose of calling to mind our age-old community, its destiny and its problems. It is a community of moral tradition, which has always shown its strength and vitality in times of stress. In all ages it has produced men who embodied the conscience of the western world, defenders of human dignity and justice.

So long as we ourselves care about this community it will continue to exist to the benefit of mankind, in spite of the fact that it possesses no self-contained organisation. A decade or two ago a group of far-sighted men, among whom Herzl of immortal memory stood out above the rest, came to the conclusion that we needed a spiritual centre in order to preserve our sense of solidarity in difficult times. Thus arose the idea of Zionism and the work of settlement in Palestine,

the successful realisation of which we have been permitted to witness, at least in its highly promising beginnings

I have had the privilege of seeing, to my great joy and satisfaction, how much this achievement has contributed to the recovery of the Jewish people, which is exposed, as a minority among the nations, not merely to external dangers but also to internal ones of a psychological nature

The crisis which the work of construction has had to face in the last few years has lain heavy upon us and is not yet completely surmounted. But the most recent reports show that the world, and especially the British government, is disposed to recognise the great things which lie behind our struggle for the Zionist ideal. Let us at this moment remember with gratitude our leader Weizmann, whose zeal and circumspection have helped the good cause to success

The difficulties we have been through have also brought some good in their train. They have shown us once more how strong the bond is which unites the Jews of all countries in a common destiny. The crisis has also purified our attitude to the question of Palestine, purged it of the dross of nationalism. It has been clearly proclaimed that we are not seeking to create a political society, but that our aim is, in accordance with the old tradition of Jewry, a cultural one in the widest sense of the word. That being so, it is for us to solve the problem of living side by side with our brother the Arab in an open, generous and worthy manner. We have here an opportunity of showing what we have learnt in the thousands of years of our martyrdom. If we choose the right path we shall succeed and give the rest of the world a fine example

Whatever we do for Palestine we do it for the honour and well-being of the whole Jewish people.

III

I am delighted to have the opportunity of addressing a few words to the youth of this country which is faithful to the common aims of Jewry. Do not be discouraged by the difficulties which confront us in Palestine. Such things serve to test the will to live of our community.

Certain proceedings and pronouncements of the English administration have been justly criticised. We must not, however, leave it at that but learn by experience.

We need to pay great attention to our relations with the Arabs. By cultivating these carefully we shall be able in future to prevent things from becoming so dangerously strained that people can take advantage of them to provoke acts of hostility. This goal is perfectly within our reach, because our work of construction has been, and must continue to be, carried out in such a manner as to serve the real interests of the Arab population also.

In this way we shall be able to avoid getting ourselves quite so often into the position, disagreeable for Jews and Arabs alike, of having to call in the mandatory power as arbitrator. We shall thereby be following not merely the dictates of Providence but also our traditions, which alone give the Jewish community meaning and stability. For that community is not, and must never become, a political one; this is the only permanent source whence it can draw new strength and the only ground on which its existence can be justified.

IV

For the last two thousand years the common property of the Jewish people has consisted entirely of its past. Scattered over the wide world, our nation possessed nothing in common except its carefully guarded tradition. Individual Jews no doubt produced great work, but it seemed as if the Jewish people as a whole had not the strength left for great collective achievements.

Now all that is changed. History has set us a great and noble task in the shape of active co-operation in the building up of Palestine. Eminent members of our race are already at work with all their might on the realisation of this aim. The opportunity is presented to us of setting up centres of civilisation which the whole Jewish people can regard as its work. We nurse the hope of erecting in Palestine a home of our own national culture which shall help to awaken the near East to new economic and spiritual life.

The object which the leaders of Zionism have in view is not a political but a social and cultural one. The community in Palestine must approach the social ideal of our forefathers as it is laid down in the Bible, and at the same time become a seat of modern intellectual life, a spiritual centre for the Jews of the whole world. In accordance with this notion, the establishment of a Jewish university in Jerusalem constitutes one of the most important aims of the Zionist organisation.

During the last few months I have been to America in order to help to raise the material basis for this university there. The success of this enterprise was quite natural. Thanks to the untiring energy and splendid

self-sacrificing spirit of the Jewish doctors in America we have succeeded in collecting enough money for the creation of a medical faculty, and the preliminary work is being started at once. After this success I have no doubt that the material basis for the other faculties will soon be forthcoming. The medical faculty is first of all to be developed as a research institute and to concentrate on making the country healthy, a most important item in the work of development. Teaching on a large scale will only become important later on. As a number of highly competent scientific workers have already signified their readiness to take up appointments at the university, the establishment of a medical faculty seems to be placed beyond all doubt. I may add that a special fund for the university, entirely distinct from the general fund for the development of the country, has been opened. For the latter considerable sums have been collected during these months in America, thanks to the indefatigable labours of Professor Weizmann and other Zionist leaders, chiefly through the self-sacrificing spirit of the middle classes. I conclude with a warm appeal to the Jews in Germany to contribute all they can, in spite of the present economic difficulties, for the building up of the Jewish home in Palestine. This is not a matter of charity but an enterprise which concerns all Jews and the success of which promises to be a source of the highest satisfaction to all.

V

For us Jews Palestine is not just a charitable or colonial enterprise, but a problem of central importance for the Jewish people. Palestine is not primarily a place of

refuge for the Jews of Eastern Europe but the embodiment of the re-awakening corporate spirit of the whole Jewish nation. Is it the right moment for this corporate sense to be awakened and strengthened? This is a question to which I feel compelled, not merely by my spontaneous feelings but on rational grounds, to return an unqualified "yes."

Let us just cast our eyes over the history of the Jews in Germany during the past hundred years. A century ago our forefathers, with few exceptions, lived in the ghetto. They were poor, without political rights, separated from the Gentiles by a barrier of religious traditions, habits of life and legal restrictions, their intellectual development was restricted to their own literature, and they had remained almost unaffected by the mighty advance of the European intellect which dates from the Renaissance. And yet these obscure, humble people had one great advantage over us: each of them belonged in every fibre of his being to a community in which he was completely absorbed, in which he felt himself a fully privileged member, and which demanded nothing of him that was contrary to his natural habits of thought. Our forefathers in those days were pretty poor specimens intellectually and physically, but socially speaking they enjoyed an enviable spiritual equilibrium.

Then came emancipation, which suddenly opened up undreamed-of possibilities to the individual. Some few rapidly made a position for themselves in the higher walks of business and social life. They greedily lapped up the splendid triumphs which the art and science of the western world had achieved. They joined in the process with burning enthusiasm, themselves making contributions of lasting value. At the

same time they imitated the external forms of Gentile life, departed more and more from their religious and social traditions, and adopted Gentile customs, manners and habits of thought. It seemed as though they were completely losing their identity in the superior numbers and more highly organised culture of the nations among whom they lived, so that in a few generations there would be no trace of them left. A complete disappearance of Jewish nationality in Central and Western Europe seemed inevitable.

But events turned out otherwise. Nationalities of different race seem to have an instinct which prevents them from fusing. However much the Jews adapted themselves, in language, manners and to a great extent even in the forms of religion, to the European peoples among whom they lived, the feeling of strangeness between the Jews and their hosts never disappeared. This spontaneous feeling is the ultimate cause of anti-Semitism, which is therefore not to be got rid of by well-meaning propaganda. Nationalities want to pursue their own path, not to blend. A satisfactory state of affairs can only be brought about by mutual toleration and respect.

The first step in that direction is that we Jews should once more become conscious of our existence as a nationality and regain the self-respect that is necessary to a healthy existence. We must learn once more to glory in our ancestors and our history and once again take upon ourselves, as a nation, cultural tasks of a sort calculated to strengthen our sense of the community. It is not enough for us to play a part as individuals in the cultural development of the human race, we must also tackle tasks which only nations as a whole can perform. Only so can the Jews regain social health.

It is from this point of view that I would have you look at the Zionist movement. To-day history has assigned to us the task of taking an active part in the economic and cultural reconstruction of our native land. Enthusiasts, men of brilliant gifts, have cleared the way, and many excellent members of our race are prepared to devote themselves heart and soul to the cause. May every one of them fully realise the importance of this work and contribute, according to his powers, to its success!

The Jewish Community

A speech in London

Ladies and Gentlemen,

It is no easy matter for me to overcome my natural inclination to a life of quiet contemplation. But I could not remain deaf to the appeal of the O.R.T. and O.Z.E. societies¹, for in responding to it I am responding, as it were, to the appeal of our sorely oppressed Jewish nation.

The position of our scattered Jewish community is a moral barometer for the political world. For what surer index of political morality and respect for justice can there be than the attitude of the nations towards a defenceless minority, whose peculiarity lies in their preservation of an ancient cultural tradition?

This barometer is low at the present moment, as we are painfully aware from the way we are treated. But it is this very lowness that confirms me in the conviction that it is our duty to preserve and consolidate our community. Embedded in the tradition of the Jewish

¹ Jewish charitable associations.

people there is a love of justice and reason which must continue to work for the good of all nations now and in the future. In modern times this tradition has produced Spinoza and Karl Marx.

Those who would preserve the spirit must also look after the body to which it is attached. The O Z E society literally looks after the bodies of our people. In Eastern Europe it is working day and night to help our people there, on whom the economic depression has fallen particularly heavily, to keep body and soul together, while the O R T society is trying to get rid of a severe social and economic handicap under which the Jews have laboured since the Middle Ages. Because we were then excluded from all directly productive occupations, we were forced into the purely commercial ones. The only way of really helping the Jew in eastern countries is to give him access to new fields of activity, for which he is struggling all over the world. This is the grave problem which the O R T society is successfully tackling.

It is to you English fellow-Jews that we now appeal to help us in this great enterprise which splendid men have set on foot. The last few years, nay, the last few days have brought us a disappointment which must have touched you in particular nearly. Do not gird at fate but rather look on these events as a reason for remaining true to the cause of the Jewish commonwealth. I am convinced that in doing that we shall also indirectly be promoting those general human ends which we must always recognise as the highest.

Remember that difficulties and obstacles are a valuable source of health and strength to any society. We should not have survived for thousands of years as a

community if our bed had been of roses, of that I am quite sure

But we have a still fairer consolation. Our friends are not exactly numerous, but among them are men of noble spirit and strong sense of justice, who have devoted their lives to uplifting human society and liberating the individual from degrading oppression.

We are happy and fortunate to have such men from the Gentile world among us to-night, their presence lends an added solemnity to this memorable evening. It gives me great pleasure to see before me Bernard Shaw and H. G. Wells, to whose view of life I am particularly attracted.

You, Mr. Shaw, have succeeded in winning the affection and joyous admiration of the world while pursuing a path that has led many others to a martyr's crown. You have not merely preached moral sermons to your fellows, you have actually mocked at things which many of them held sacred. You have done what only the born artist can do. From your magic box you have produced innumerable little figures which, while resembling human beings, are compact not of flesh and blood but of brains, wit and charm. And yet in a way they are more human than we are ourselves, and one almost forgets that they are creations not of nature but of Bernard Shaw. You make these charming little figures dance in a miniature world in front of which the Graces stand sentinel and permit no bitterness to enter. He who has looked into this little world sees our actual world in a new light, its puppets insinuate themselves into real people, making them suddenly look quite different. By thus holding the mirror up to us all you have had a liberating effect on us such as hardly any other of our contemporaries has done and

have relieved life of something of its earth-bound heaviness. For this we are all devoutly grateful to you, and also to fate, which along with grievous plagues has also given us the physician and liberator of our souls. I personally am also grateful to you for the unforgettable words which you have addressed to my mythical namesake who makes life so difficult for me, although he is really, for all his clumsy, formidable size, quite a harmless fellow.

To you all I say that the existence and destiny of our people depends less on external factors than on ourselves remaining faithful to the moral traditions which have enabled us to survive for thousands of years despite the heavy storms that have broken over our heads. In the service of life sacrifice becomes grace.

Working Palestine

Among Zionist organisations "Working Palestine" is the one whose work is of most direct benefit to the most valuable class of people living there, namely those who are transforming deserts into flourishing settlements by the labour of their hands. These workers are a selection, made on a voluntary basis, from the whole Jewish nation, an élite composed of strong, confident and unselfish people. They are not ignorant labourers who sell the labour of their hands to the highest bidder, but educated, intellectually vigorous, free men, from whose peaceful struggle with a neglected soil the whole Jewish nation are the gainers, directly and indirectly. By lightening their heavy lot as far as we can we shall be saving the most valuable sort of human life; for the first settlers' struggle on ground not yet made habitable

is a difficult and dangerous business involving a heavy personal sacrifice. How true this is, only they can judge who have seen it with their own eyes. Anyone who helps to improve the equipment of these men is helping on the good work at a crucial point.

It is, moreover, this working class alone that has it in its power to establish healthy relations with the Arabs, which is the most important political task of Zionism. Administrations come and go; but it is human relations that finally turn the scale in the lives of nations. Therefore to support "Working Palestine" is at the same time to promote a humane and worthy policy in Palestine and to oppose an effective resistance to those undercurrents of narrow nationalism from which the whole political world, and in a less degree the small political world of Palestine affairs, is suffering.

Jewish Recovery

I gladly accede to your paper's request that I should address an appeal to the Jews of Hungary on behalf of Keren Hajessod.

The greatest enemies of the national consciousness and honour of the Jews are fatty degeneration—by which I mean the unconscionableness which comes from wealth and ease—and a kind of inner dependence on the surrounding Gentile world which comes from the loosening of the fabric of Jewish society. The best in man can only flourish when he loses himself in a community. Hence the moral danger of the Jew who has lost touch with his own people and is regarded as a foreigner by the people of his adoption. Only too often a contemptible and joyless egoism has resulted from such circumstances. The weight of outward

oppression on the Jewish people is particularly heavy at the moment. But this very bitterness has done us good. A revival of Jewish national life, such as the last generation could never have dreamed of, has begun. Through the operation of a newly awakened sense of solidarity among the Jews, the scheme of colonising Palestine, launched by a handful of devoted and judicious leaders in the face of apparently insuperable difficulties, has already prospered so far that I feel no doubt about its permanent success. The value of this achievement for the Jews everywhere is very great. Palestine will be a centre of culture for all Jews, a refuge for the most grievously oppressed, a field of action for the best among us, a unifying ideal, and a means of attaining inward health for the Jews of the whole world.

Anti-Semitism and Academic Youth

So long as we lived in the ghetto our Jewish nationality involved for us material difficulties and sometimes physical danger, but no social or psychological problems. With emancipation the position changed, particularly for those Jews who turned to the intellectual professions. In school and at the university the young Jew is exposed to the influence of a society with a definite national tinge, which he respects and admires, from which he receives his mental sustenance, to which he feels himself to belong, while it, on the other hand, treats him, as one of an alien race, with a certain contempt and hostility. Driven by the suggestive influence of this psychological superiority rather than by utilitarian considerations, he turns his back on his people and his traditions, and considers himself as belonging entirely to the others while he tries in vain to conceal

from himself and them the fact that the relation is not reciprocal. Hence that pathetic creature, the baptised Jewish *Geheimrat* of yesterday and to-day. In most cases it is not pushfulness and lack of character that have made him what he is but, as I have said, the suggestive power of an environment superior in numbers and influence. He knows, of course, that many admirable sons of the Jewish people have made important contributions to the glory of European civilisation; but have they not all, with a few exceptions, done much the same as he?

In this case, as in many mental disorders, the cure lies in a clear knowledge of one's condition and its causes. We must be conscious of our alien race and draw the logical conclusions from it. It is no use trying to convince the others of our spiritual and intellectual equality by arguments addressed to the reason, when their attitude does not originate in their intellects at all. Rather must we emancipate ourselves socially and supply our social needs, in the main, ourselves. We must have our own students' societies and adopt an attitude of courteous but consistent reserve to the Germans. And let us live after our own fashion there and not ape duelling and drinking customs which are foreign to our nature. It is possible to be a civilised European and a good citizen and at the same time a faithful Jew who loves his race and honours his fathers. If we remember this and act accordingly, the problem of anti-Semitism, in so far as it is of a social nature, is solved for us.

A Letter to Professor Dr. Hellpach, Minister of State

Dear Herr Hellpach,

I have read your article on Zionism and the Zurich Congress and feel, as a strong devotee of the Zionist idea, that I must answer you, even if it is only shortly.

The Jews are a community bound together by ties of blood and tradition, and not of religion only: the attitude of the rest of the world towards them is sufficient proof of this. When I came to Germany fifteen years ago I discovered for the first time that I was a Jew, and I owe this discovery more to Gentiles than Jews.

The tragedy of the Jews is that they are people of a definite historical type, who lack the support of a community to keep them together. The result is a want of solid foundations in the individual which amounts in its extremest forms to moral instability. I realised that the only possible salvation for the race was that every Jew in the world should become attached to a living society to which the individual rejoiced to belong and which enabled him to bear the hatred and the humiliations that he has to put up with from the rest of the world.

I saw worthy Jews basely caricatured, and the sight made my heart bleed. I saw how schools, comic papers and innumerable other forces of the Gentile majority undermined the confidence even of the best of my fellow-Jews, and felt that this could not be allowed to continue.

Then I realised that only a common enterprise dear to the hearts of Jews all over the world could restore this people to health. It was a great achievement of

Herzl's to have realised and proclaimed at the top of his voice that, the traditional attitude of the Jews being what it was, the establishment of a national home or, more accurately, a centre in Palestine, was a suitable object on which to concentrate our efforts.

All this you call nationalism, and there is something in the accusation. But a communal purpose, without which we can neither live nor die in this hostile world, can always be called by that ugly name. In any case it is a nationalism whose aim is not power but dignity and health. If we did not have to live among intolerant, narrow-minded and violent people, I should be the first to throw over all nationalism in favour of universal humanity.

The objection that we Jews cannot be proper citizens of the German state, for example, if we want to be a "nation," is based on a misunderstanding of the nature of the state which springs from the intolerance of national majorities. Against that intolerance we shall never be safe, whether we call ourselves a "people" (or "nation") or not.

I have put all this with brutal frankness for the sake of brevity, but I know from your writings that you are a man who attends to the sense, not the form.

Letter to an Arab

March 15th, 1930

Sir,

Your letter has given me great pleasure. It shows me that there is good will available on your side too for solving the present difficulties in a manner worthy of both our nations. I believe that these difficulties are more psychological than real, and that they can be got

over if both sides bring honesty and good will to the task

What makes the present position so bad is the fact that Jews and Arabs confront each other as opponents before the mandatory power. This state of affairs is unworthy of both nations and can only be altered by our finding a *via media* on which both sides agree

I will now tell you how I think that the present difficulties might be remedied, at the same time I must add that this is only my personal opinion; which I have discussed with nobody I am writing this letter in German because I am not capable of writing it in English myself and because I want myself to bear the entire responsibility for it You will, I am sure, be able to get some Jewish friend of conciliation to translate it

A Privy Council is to be formed to which the Jews and Arabs shall each send four representatives, who must be independent of all political parties

Each group to be composed as follows —

A doctor, elected by the Medical Association;

A lawyer, elected by the lawyers,

A working men's representative, elected by the trade unions,

An ecclesiastic, elected by the ecclesiastics

These eight people are to meet once a week They undertake not to espouse the sectional interests of their profession or nation but conscientiously and to the best of their power to aim at the welfare of the whole population of the country. Their deliberations shall be secret and they are strictly forbidden to give any information about them, even in private When a decision has been reached on any subject in which not

less than three members on each side concur, it may be published, but only in the name of the whole Council. If a member dissents he may retire from the Council, but he is not thereby released from the obligation to secrecy. If one of the elective bodies above specified is dissatisfied with a resolution of the Council, it may replace its representative by another.

Even if it is "Privy Council" has no definite powers it may nevertheless bring about the gradual composition of differences, and secure a united representation of the common interests of the country before the mandatory power, clear of the dust of ephemeral politics.

Christianity and Judaism

If one purges the Judaism of the Prophets and Christianity as Jesus Christ taught it of all subsequent additions, especially those of the priests, one is left with a teaching which is capable of curing all the social ills of humanity.

It is the duty of every man of good will to strive steadfastly in his own little world to make this teaching of pure humanity a living force so far as he can. If he makes an honest attempt in this direction without being crushed and trampled under foot by his contemporaries he may consider himself and the community to which he belongs lucky.

A Foreword

The following pages are devoted to an appreciation of the achievements of the German Jews. It must be remembered that we are concerned here with a body of people amounting in numbers, to no more than the

population of a moderate-sized town, who have held their own against a hundred times as many Germans, in spite of handicaps and prejudices, through the superiority of their ancient cultural traditions. Whatever attitude people may take up towards this little people, nobody who retains a shred of sound judgment in these times of confusion can deny them respect. In these days of the persecution of the German Jews especially, it is time to remind the western world that it owes to the Jewish people (a) its religion and therewith its most valuable moral ideals, and (b), to a large extent, the resurrection of the world of Greek thought. Nor should it be forgotten that it was a translation of the Bible, that is to say, a translation from Hebrew, which brought about the refinement and perfection of the German language. To-day the Jews of Germany find their fairest consolation in the thought of all they have produced and achieved for humanity by their efforts in modern times also, and no oppression however brutal, no campaign of calumny however subtle will blind those who have eyes to see to the intellectual and moral qualities inherent in this people.

PART V
SCIENTIFIC

the use of mathematical language can give. As regards its subject-matter, on the other hand, the physicist has to limit himself very severely. he must content himself with describing the most simple events which can be brought within the domain of our experience; all events of a more complex order are beyond the power of the human intellect to reconstruct with the subtle accuracy and logical perfection which the theoretical physicist demands. Supreme purity, clarity and certainty are attained only by the sacrifice of completeness. But what can be the attraction of getting to know such a tiny section of nature thoroughly, while one leaves everything subtler and more complex shyly and timidly alone? Does the product of such a modest effort deserve to be called by the proud name of a theory of the Universe?

In my belief the name is justified, for the general laws on which the structure of theoretical physics is based claim to be valid for any natural phenomenon whatsoever. With them, it ought to be possible to arrive at the description, that is to say, the theory, of every natural process, including life, by means of pure deduction, if that process of deduction were not far beyond the capacity of the human intellect. The physicist's renunciation of completeness for his cosmos is therefore not a matter of fundamental principle.

The supreme task of the physicist is to arrive at those universal elementary laws from which the cosmos can be built up by pure deduction. There is no logical path to these laws, only intuition, resting on sympathetic understanding of experience, can reach them. In this methodological uncertainty, one might suppose that there were any number of possible systems of

theoretical physics all with an equal amount to be said for them, and this opinion is no doubt correct, theoretically. But evolution has shown that at any given moment out of all conceivable constructions one has always proved itself absolutely superior to all the rest. Nobody who has really gone deeply into the matter will deny that in practice the world of phenomena unambiguously determines the theoretical system, in spite of the fact that there is no logical bridge between phenomena and their theoretical principles, this is what Leibnitz described so happily as a "pre-established harmony." Physicists often accuse epistemologists of not paying sufficient attention to this fact. Here, it seems to me, lie the roots of the controversy carried on some years ago between Mach and Planck.

The longing to behold this pre-established harmony is the source of the inexhaustible patience and endurance with which Planck has devoted himself, as we see, to the most general problems of our science, refusing to let himself be diverted to more grateful and more easily attained ends. I have often heard colleagues try to attribute this attitude of his to extraordinary will-power and discipline—wrongly, in my opinion. The state of mind which enables a man to do work of this kind is akin to that of the religious worshipper or the lover; the daily effort comes from no deliberate intention or programme, but straight from the heart. There he sits, our beloved Planck, and smiles inside himself at my childish poking-about with the lantern of Diogenes. Our affection for him needs no threadbare explanation. May the love of science continue to illumine his path in the future and lead him to the solution of the most important problem in present-day physics, which he has himself posed and done so much to solve! May he

succeed in uniting the quantum-theory and electrodynamics in a single logical system!

Inaugural Address to the Prussian Academy of Sciences.
(1914)

Gentlemen,

First of all, I have to thank you most heartily for conferring the greatest benefit on me that anybody can confer on such an one as myself. By electing me to your Academy you have freed me from the distractions and cares of a professional life and so made it possible for me to devote myself entirely to scientific studies. I beg that you will continue to believe in my gratitude and my industry even when my efforts seem to you to yield but a poor result.

Perhaps I may be allowed à propos of this to make a few general remarks on the relation of my sphere of activity, which is theoretical physics, to experimental physics. A mathematician friend of mine said to me the other day half in jest "The mathematician can do a lot of things, but never what you happen to want just at the moment." Much the same often applies to the theoretical physicist when the experimental physicist calls him in. What is the reason for this peculiar lack of adaptability?

The theorist's method involves his using as his foundation general postulates or 'principles' from which he can deduce conclusions. His work thus falls into two parts. He must first discover his principles and then draw the conclusions which follow from them. For the second of these tasks he receives an admirable equipment at school. Once, therefore, he has performed the first in some department or for some com-

plex of related phenomena, he is certain of success, provided his industry and intelligence are adequate. The first of these tasks, namely, that of establishing the principles which are to serve as the starting-point of his deduction, is of an entirely different nature. Here there is no method capable of being learnt and systematically applied that leads to the goal. The scientist has to worm these general principles out of nature by perceiving certain general features, which permit of precise formulation, in large complexes of empirical facts.

Once this formulation is successfully accomplished, inference follows on inference, often revealing relations which extend far beyond the province of reality from which the principles were originally drawn. But as long as the principles capable of serving as starting-points for the deduction remain undiscovered, the individual fact is of no use to the theorist, indeed he cannot even do anything with isolated empirical generalisations of more or less wide application. No, he has to persist in his helpless attitude towards the separate results of empirical research, until principles which he can make the basis of deductive reasoning have revealed themselves to him.

This is the kind of position in which theory finds itself at present in regard to the laws of heat-radiation and molecular movement at low temperatures. About fifteen years ago nobody yet doubted that a correct account of the electrical, optical and thermal properties of bodies was possible on the basis of Galileo-Newtonian mechanics applied to the movement of molecules and of Clerk Maxwell's theory of the electro-magnetic field. Then Planck showed that in order to establish a law of heat-radiation consonant with experience, it

was necessary to employ a method of calculation whose incompatibility with the principles of classical physics became clearer and clearer. For with this method of calculation Planck introduced the quantum-hypothesis into physics, which has since received brilliant confirmation. With this quantum-hypothesis he dethroned classical physics as applied to the case where sufficiently small masses are moved at sufficiently low speeds and high rates of acceleration, so that to-day the laws of motion propounded by Galileo and Newton can only be allowed validity as limiting laws. In spite of assiduous efforts, however, the theorists have not yet succeeded in replacing the principles of mechanics by others which fit in with Planck's law of heat-radiation or the quantum-hypothesis. No matter how definitely it has been proved that heat is to be explained by molecular movement, we have nevertheless to admit to-day that our position in regard to the fundamental laws of this motion resembles that of astronomers before Newton in regard to the motions of the planets.

I have just now referred to a group of facts for the theoretical treatment of which the principles are lacking. But it may equally well happen that clearly formulated principles lead to conclusions which fall entirely, or almost entirely, outside the sphere of reality at present accessible to our experience. In that case it may need many years of empirical research to ascertain whether the theoretical principles correspond with reality. We have an instance of this in the theory of relativity.

An analysis of the fundamental concepts of space and time has shown us that the principle of the constant velocity of light in empty space, which emerges from the optics of bodies in motion, by no means forces us to accept the theory of a stationary luminiferous ether.

On the contrary, there is nothing to prevent our framing a general theory which takes account of the fact that in experiments carried out on the earth we are wholly unconscious of the earth's translatory motion. This involves using the principle of relativity, which says that the laws of nature do not alter their form when one proceeds from the original (correctly chosen) system of co-ordinates to a new one which is in *uniform* translatory motion with respect to it. This theory has received impressive confirmation from experience and has led to a simplification of the theoretical description of groups of facts already connected together.

On the other hand, from the theoretical point of view this theory is not wholly satisfactory, because the principle of relativity just formulated prefers *uniform* motion. If it is true that no absolute significance can be attached to *uniform* motion from the physical point of view, the question arises whether this statement must not also be extended to *non-uniform* motions. It has become clear that one arrives at a quite definite enlargement of the relativity theory if one postulates a principle of relativity in this extended sense. One is led thereby to a general theory of gravitation which includes dynamics. For the present, however, we have not the necessary array of facts to test the legitimacy of our introduction of the postulated principle.

We have ascertained that inductive physics asks questions of deductive, and vice versa to answer which demands the exertion of all our energies. May we soon succeed in making permanent progress by our united efforts!

Scientific Truth

(1) It is difficult even to attach a precise meaning to the term "scientific truth." So different is the meaning of the word "truth" according as we are dealing with a fact of experience, a mathematical proposition or a scientific theory. "Religious truth" conveys nothing clear to me at all.

(2) Scientific research can reduce superstition by encouraging people to think and survey things in terms of cause and effect. Certain it is that a conviction, akin to religious feeling, of the rationality or intelligibility of the world lies behind all scientific work of a higher order.

(3) The firm belief, which is bound up with deep feeling, in a superior mind revealing itself in the world of experience, represents my conception of God, which may therefore be described in common parlance as "pantheistic" (Spinoza).

(4) Denominational traditions I can only consider historically and psychologically; they have no other significance for me.

The Method of Theoretical Physics

If you want to find out anything from the theoretical physicists about the methods they use, I advise you to stick closely to one principle: don't listen to their words, fix your attention on their deeds. To the discoverer in this field the products of his imagination appear so necessary and natural that he regards them, and would have them regarded by others, not as creations of thought but as given realities.

These words sound like an invitation to you to walk

out of this lecture. You will say to yourselves: the fellow's a working physicist himself, and ought therefore to leave all questions of the structure of theoretical science to the epistemologists.

Against such criticism I can defend myself from the personal point of view by assuring you that it is not at my own instance but at the kind invitation of others that I have mounted this rostrum, which serves to commemorate a man who fought hard all his life for the unity of knowledge. Objectively, however, my enterprise can be justified on the ground that it may, after all, be of interest to know how one looks upon his own branch of science who has spent a lifetime in striving with all his might to clear up and rectify its fundamentals. The way in which he regards its past and present may depend too much on what he hopes for the future and aims at in the present, but that is the inevitable fate of anybody who has occupied himself intensively with a world of ideas. The same thing happens to him as to the historian, who in the same way, even though perhaps unconsciously, groups actual events round ideals which he has formed for himself on the subject of human society.

Let us now cast an eye over the development of the theoretical system, paying special attention to the relations between the content of the theory and the totality of empirical fact. We are concerned with the eternal antithesis between the two inseparable components of our knowledge, the empirical and the rational, in our department.

We reverence ancient Greece as the cradle of western science. Here for the first time the world witnessed the miracle of a logical system which proceeded from step to step with such precision that every single one

of its propositions was absolutely indubitable—I refer to Euclid's geometry. This admirable triumph of reasoning gave the human intellect the confidence in itself necessary for its subsequent achievements. If Euclid fails to kindle your youthful enthusiasm, then you were not born to be a scientific thinker.

But before mankind could be ripe for a science which takes in the whole of reality, a second fundamental truth was needed, which only became common property among philosophers with the advent of Kepler and Galileo. Pure logical thinking cannot yield us any knowledge of the empirical world, all knowledge of reality starts from experience and ends in it. Propositions arrived-at by purely logical means are completely empty as regards reality. Because he saw this, and particularly because he drummed it into the scientific world, Galileo was the father of modern physics—indeed, of modern science altogether.

If, then, experience is the alpha and the omega of all our knowledge of reality, what is the function of pure reason in science?

A complete system of theoretical physics is made up of concepts, fundamental laws which are supposed to be valid for those concepts, and conclusions to be reached by logical deduction. It is these conclusions which must correspond with our separate experiences, in any theoretical treatise their logical deduction occupies almost the whole book.

This is exactly what happens in Euclid's geometry, except that there the fundamental laws are called axioms and there is no question of the conclusions having to correspond to any sort of experience. If, however, one regards Euclidean geometry as the science of the mutual positional relations of practically rigid bodies in space,

that is to say, treats it as a physical science, without abstracting from its original empirical content, the logical homogeneity of geometry and theoretical physics becomes complete

We have thus assigned to pure reason and experience their places in a theoretical system of physics. The structure of the system is the work of reason, the empirical contents and their mutual relations must find their representation in the conclusions of the theory. In the possibility of such a representation lies the sole value and justification of the whole system, and especially of the concepts and fundamental principles which underlie it. These latter, by the way, are free inventions of the human intellect, which cannot be justified either by the nature of that intellect or in any other fashion *a priori*.

These fundamental concepts and postulates, which cannot be further reduced logically, form the essential part of a theory, which reason cannot touch. It is the grand object of all theory to make these irreducible elements as simple and as few in number as possible, without having to renounce the adequate representation of any empirical content whatever.

The view I have just outlined of the purely fictitious character of the fundamentals of scientific theory was by no means the prevailing one in the eighteenth or even the nineteenth century. But it is steadily gaining ground from the fact that the distance in thought between the fundamental concepts and laws on one side and, on the other, the conclusions which have to be brought into relation with our experience grows larger and larger, the simpler the logical structure becomes—that is to say, the smaller the number of logically independent conceptual elements which are found necessary to support the structure.

Newton, the first creator of a comprehensive, workable system of theoretical physics, still believed that the basic concepts and laws of his system could be derived from experience. This is no doubt the meaning of his saying, *hypotheses non fingo*.

Actually the concepts of time and space appeared at that time to present no difficulties. The concepts of mass, inertia and force, and the laws connecting them seemed to be drawn directly from experience. Once this basis is accepted, the expression for the force of gravitation appears derivable from experience, and it was reasonable to hope for the same in regard to other forces.

We can indeed see from Newton's formulation of it that the concept of absolute space, which comprised that of absolute rest, made him feel uncomfortable; he realised that there seemed to be nothing in experience corresponding to this last concept. He was also not quite comfortable about the introduction of forces operating at a distance. But the tremendous practical success of his doctrines may well have prevented him and the physicists of the eighteenth and nineteenth centuries from recognising the fictitious character of the foundations of his system.

The natural philosophers of those days were, on the contrary, most of them possessed with the idea that the fundamental concepts and postulates of physics were not in the logical sense free inventions of the human mind but could be deduced from experience by "abstraction"—that is to say by logical means. A clear recognition of the erroneousness of this notion really only came with the general theory of relativity, which showed that one could take account of a wider range of empirical facts, and that too in a more satisfactory and

complete manner, on a foundation quite different from the Newtonian than was possible with it. But quite apart from the question which is superior, the fictitious character of fundamental principles is perfectly evident from the fact that we can point to two essentially different principles, both of which correspond with experience to a large extent, this proves at the same time that every attempt at a logical deduction of the basic concepts and postulates of mechanics from elementary experiences is doomed to failure.

If, then, it is true that this axiomatic basis of theoretical physics cannot be extracted from experience but must be freely invented, can we ever hope to find the right way? Nay, more, has this right way any existence outside our illusions? Can we hope to be guided in the right way by experience when there exist theories (such as classical mechanics) which to a large extent do justice to experience, without getting to the root of the matter? I answer without hesitation that there is, in my opinion, a right way, and that we are capable of finding it. Our experience hitherto justifies us in believing that nature is the realisation of the simplest conceivable mathematical ideas. I am convinced that we can discover by means of purely mathematical constructions the concepts and the laws connecting them with each other, which furnish the key to the understanding of natural phenomena. Experience may suggest the appropriate mathematical concepts, but they most certainly cannot be deduced from it. Experience remains, of course, the sole criterion of the physical utility of a mathematical construction. But the creative principle resides in mathematics. In a certain sense, therefore, I hold it true that pure thought can grasp reality, as the ancients dreamed.

In order to justify this confidence, I am compelled

to make use of a mathematical conception. The physical world is represented as a four-dimensional continuum. If I assume a Riemannian metric in it and ask what are the simplest laws which such a metric can satisfy, I arrive at the relativist theory of gravitation in empty space. If in that space I assume a vector-field or an anti-symmetrical tensor-field which can be inferred from it, and ask what are the simplest laws which such a field can satisfy, I arrive at Clerk Maxwell's equations for empty space.

At this point we still lack a theory for those parts of space in which electrical density does not disappear. De Broglie conjectured the existence of a wave-field, which served to explain certain quantum properties of matter. Dirac found in the spinors field-magnitudes of a new sort, whose simplest equations enable one to a large extent to deduce the properties of the electron. Subsequently I discovered, in conjunction with my colleague, that these spinors form a special case of a new sort of field, mathematically connected with the four-dimensional system, which we called "semivectors." The simplest equations to which such semivectors can be reduced furnish a key to the understanding of the existence of two sorts of elementary particles, of different ponderable mass and equal but opposite electrical charge. These semivectors are, after ordinary vectors, the simplest mathematical fields that are possible in a metrical continuum of four dimensions, and it looks as if they described, in an easy manner, certain essential properties of electrical particles.

The important point for us to observe is that all these constructions and the laws connecting them can be arrived at by the principle of looking for the mathematically simplest concepts and the links between them.

In the limited nature of the mathematically existent simple fields and the simple equations possible between them lies the theorist's hope of grasping the real in all its depth

Meanwhile the great stumbling-block for a field-theory of this kind lies in the conception of the atomic structure of matter and energy. For the theory is fundamentally non-atomic in so far as it operates exclusively with continuous functions of space, in contrast to classical mechanics, whose most important element, the material point, in itself accounts for the atomic structure of matter.

The modern quantum theory in the form associated with the names of de Broglie, Schrodinger, and Dirac, which operates with continuous functions, has overcome these difficulties by a bold piece of interpretation which was first given a clear form by Max Born. According to this, the spatial functions which appear in the equations make no claim to be a mathematical model of the atomic structure. Those functions are only supposed to determine the mathematical probabilities of such structures occurring if measurements were taken at a particular spot or in a certain state of motion. This notion is logically unobjectionable and has important successes to its credit. Unfortunately, however, it compels one to use a continuum the number of whose dimensions is not that ascribed to space by physics hitherto (four) but rises indefinitely with the number of the particles constituting the system under consideration. I cannot but confess that I attach only a transitory importance to this interpretation. I still believe in the possibility of a model of reality—that is to say, of a theory which represents things themselves and not merely the probability of their occurrence.

On the other hand it seems to me certain that we must give up the idea of a complete localisation of the particles in a theoretical model. This seems to me to be the permanent upshot of Heisenberg's Uncertainty Principle. But an atomic theory in the true sense of the word (not merely on the basis of an interpretation), without localisation of particles in a mathematical model, is perfectly thinkable. For instance, to account for the atomic character of electricity, the field equations need only lead to the following conclusion:—A portion of space (three-dimensional) at whose boundaries electrical density everywhere disappears, always contains a total electrical charge whose size is represented by a whole number. In a continuum-theory, atomic characteristics would be satisfactorily expressed by integral laws without localisation of the formation which constitutes the atomic structure.

Not until the atomic structure had been successfully represented in such a manner would I consider the quantum-riddle solved.

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Science as something existing and complete is the most objective thing known to man. But science in the making, science as an end to be pursued, is as subjective and psychologically conditioned as any other branch of human endeavour—so much so that the question, What is the purpose and meaning of science? receives quite different answers at different times and from different sorts of people.

It is, of course, universally agreed that science has to establish connections between the facts of experience, of such a kind that we can predict further occurrences

from those already experienced. Indeed, according to the opinion of many positivists the completest possible accomplishment of this task is the only end of science.

I do not believe, however, that so elementary an ideal could do much to kindle the investigator's passion, from which really great achievements have arisen. Behind the tireless efforts of the investigator there lurks a stronger, more mysterious drive: it is existence and reality that one wishes to comprehend. But one shrinks from the use of such words, for one soon gets into difficulties when one has to explain what is really meant by "reality" and by "comprehend" in such a general statement.

When we strip the statement of its mystical elements we mean that we are seeking for the simplest possible system of thought which will bind together the observed facts. By the "simplest" system we do not mean the one which the student will have the least trouble in assimilating, but the one which contains the fewest possible mutually independent postulates or axioms, since the content of these logical, mutually independent axioms represents that remainder which is not comprehended.

When a man is talking about scientific subjects, the little word "I" should play no part in his exposition. But when he is talking about the purposes and aims of science, he should be permitted to speak of himself, for a man experiences no aims and desires so immediately as his own. The special aim which I have constantly kept before me is logical unification in the field of physics. To start with, it disturbed me that electrodynamics should pick out *one* state of motion in preference to others, without any experimental justification for this preferential treatment. Thus arose the special

theory of relativity, which, moreover, welded together into comprehensible unities the electrical and magnetic fields, as well as mass and energy, or momentum and energy, as the case may be. Then out of the endeavour to understand inertia and gravitation as having a unified character there arose the general theory of relativity, which also avoided those implicit axioms which underlie our thinking when we use special co-ordinate systems in the process of formulating basic laws.

At the present time it is particularly disturbing that the gravitational field and the electrical field should enter into the theory as mutually independent fundamental concepts. After many years of effort, however, an appropriate logical unification has been achieved—so I believe—through a new mathematical method, which I have invented together with my distinguished collaborator, Dr. W. Mayer.

In the meantime there still remains outstanding an important problem of the same kind, which has often been propounded but has so far found no satisfactory solution—namely the explanation of atomic structure in terms of field-theory. All these endeavours are based on the conviction that existence should have a completely harmonious structure. To-day we have less ground than ever before for allowing ourselves to be forced away from this wonderful belief.

Johannes Kepler

In anxious and uncertain times like ours, when it is difficult to find pleasure in humanity and the course of human affairs, it is particularly consoling to think of the serene greatness of a Kepler. Kepler lived in an age in which the reign of law in nature was by no means

an accepted certainty. How great must his faith in natural law have been, to have given him the strength to devote ten years of hard and patient work to the empirical investigation of the movement of the planets and the mathematical laws of that movement, entirely on his own account, supported by no one and understood by very few! If we would honour his memory worthily, we must get as clear a picture as we can of his problem and the stages of its solution.

Copernicus had opened the eyes of the most intelligent to the fact that the best way to get a clear grasp of the apparent movements of the planets in the heavens was by regarding them as movements round the sun conceived as stationary. If the planets moved uniformly in a circle round the sun, it would have been comparatively easy to discover how these movements must look from the earth. Since, however, the phenomena to be dealt with were much more complicated than that, the task was a far harder one. The first thing to be done was to determine these movements empirically from the observations of Tycho Brahe. Only then did it become possible to think about discovering the general laws which these movements satisfy.

To grasp how difficult a business it was even to find out about the actual movements of revolution, one has to realise the following. One can never see where a planet really is at any given moment, but only in what direction it is seen just then from the earth, which however, is itself moving in an unknown manner round the sun. The difficulties thus seemed practically unsurmountable.

Kepler had to discover a way of bringing order into this chaos. To start with, he saw that it was necessary first to try to find out about the motion of the earth itself. This would have been simply impossible if

there had existed only the sun, the earth and the ~~fixed~~ stars, but no other planets. For in that case one could ascertain nothing empirically except how the direction of the straight line sun-earth changes in the course of the year (apparent movement of the sun with reference to the fixed stars). In this way it was possible to discover that these directions all lay in a plane stationary with reference to the fixed stars, at least with the accuracy of observation achieved in those days, when there were no telescopes. By this means it could also be ascertained in what manner the line sun-earth revolves round the sun. It turned out that the angular velocity of this motion went through a regular change in the course of the year. But this was not of much use, as it was still not known how the distance between the earth and the sun alters in the course of the year. It was only when these changes were known that the real shape of the earth's orbit and the manner in which it is described were discovered.

Kepler found a marvellous way out of this dilemma. In the first place, it followed from the observations of the sun that the apparent path of the sun against the background of the fixed stars differed in speed at different times of the year, but that the angular velocity of this movement was always the same at the same point in the astronomical year, and therefore that the speed of rotation of the straight line earth-sun was always the same when it pointed to the same region of the fixed stars. It was thus legitimate to suppose that the earth's orbit was a self-enclosed one, described by the earth in the same way every year—which was by no means obvious *a priori*. For the adherent of the Copernican system it was thus as good as certain that this must also apply to the orbits of the rest of the planets.

This certainly made things easier. But how to ascertain the real shape of the earth's orbit? Imagine a brightly shining lantern M somewhere in the plane of the orbit. We know that this lantern remains permanently in its place and thus forms a kind of fixed triangulation-point for determining the earth's orbit, a point which the inhabitants of the earth can take a sight on at any time of year. Let this lantern M be farther away from the sun than the earth. With the help of such a lantern it was possible to determine the earth's orbit, in the following way —

First of all, in every year there comes a moment when the earth E lies exactly on the line joining the sun S and the lantern M. If at this moment we look from the earth E at the lantern M, our line of sight will coincide with the line SM (sun-lantern). Suppose the latter to be marked in the heavens. Now imagine the earth in a different position and at a different time. Since the sun S and the lantern M can both be seen from the earth, the angle at E in the triangle SEM is known. But we also know the direction of SE in relation to the fixed stars through direct solar observations, while the direction of the line SM in relation to the fixed stars was finally ascertained previously. But in the triangle SEM we also know the angle at S. Therefore, with the base SM arbitrarily laid down on a sheet of paper, we can, in virtue of our knowledge of the angles at E and S, construct the triangle SEM. We might do this at frequent intervals during the year, each time we should get on our piece of paper a position of the earth E with a date attached to it and a certain position in relation to the permanently fixed base SM. The earth's orbit would thereby be empirically determined, apart from its absolute size, of course.

But, you will say, where did Kepler get his lantern? His genius and Nature, benevolent in this case, gave it to him. There was, for example, the planet Mars, and the length of the Martian year—i.e., one rotation of Mars round the sun—was known. It may happen one fine day that the sun, the earth and Mars lie absolutely in the same straight line. This position of Mars regularly recurs after one, two, etc. Martian years, as Mars has a self-enclosed orbit. At these known moments, therefore, SM always presents the same base, while the earth is always at a different point in its orbit. The observations of the sun and Mars at these moments thus constitute a means of determining the true orbit of the earth, as Mars then plays the part of our imaginary lantern. Thus it was that Kepler discovered the true shape of the earth's orbit and the way in which the earth describes it, and we who come after—Europeans, Germans, or even Swabians—may well admire and honour him for it.

Now that the earth's orbit had been empirically determined, the true position and length of the line SE at any moment was known, and it was not so terribly difficult for Kepler to calculate the orbit and motions of the rest of the planets too from observations—at least in principle. It was nevertheless an immense work, especially considering the state of mathematics at the time.

Now came the second and no less arduous part of Kepler's life-work. The orbits were empirically known, but their laws had to be deduced from the empirical data. First he had to make a guess at the mathematical nature of the curve described by the orbit, and then try it out on a vast assemblage of figures. If it did not fit, another hypothesis had to be devised and again tested. After tremendous search, the conjecture that

the orbit was an ellipse with the sun at one of its foci was found to fit the facts. Kepler also discovered the law governing the variation in speed during rotation, which is that the line sun-planet sweeps out equal areas in equal periods of time. Finally he also discovered that the square of the period of circulation round the sun varies as the cube of the major axes of the ellipse.

Our admiration for this splendid man is accompanied by another feeling of admiration and reverence, the object of which is no man but the mysterious harmony of nature into which we are born. As far back as ancient times people devised the lines exhibiting the simplest conceivable form of regularity. Among these, next to the straight line and the circle, the most important were the ellipse and the hyperbola. We see the last two embodied—at least very nearly so—in the orbits of the heavenly bodies.

It seems that the human mind has first to construct forms independently before we can find them in things. Kepler's marvellous achievement is a particularly fine example of the truth that knowledge cannot spring from experience alone but only from the comparison of the inventions of the intellect with observed fact.

*The Mechanics of Newton and their Influence on the
Development of Theoretical Physics*

It is just two hundred years ago since Newton closed his eyes for the last time. It behoves us at such a moment to remember this brilliant genius, who determined the course of western thought, research and practice to an extent that nobody before or since his time can touch. Not only was he brilliant as an inventor of certain key methods, but he also had a unique com-

mand of the empirical material available in his day, and he was marvellously inventive as regards mathematical and physical methods of proof in individual cases. For all these reasons he deserves our deepest reverence. The figure of Newton has, however, an even greater importance than his genius warrants from the fact that destiny placed him at a turning-point in the history of the human intellect. To see this vividly, we have to remind ourselves that before Newton there existed no self-contained system of physical causality which was capable of representing any of the deeper features of the empirical world.

No doubt the great materialists of ancient Greece had insisted that all material events should be traced back to a strictly regular series of atomic movements, without admitting any living creature's will as an independent cause. And no doubt Descartes had in his own way taken up this quest again. But it remained a bold ambition, the problematical ideal of a school of philosophers. Actual results of a kind to support the belief in the existence of a complete chain of physical causation hardly existed before Newton.

Newton's object was to answer the question, 'Is there such a thing as a simple rule by which one can calculate the movements of the heavenly bodies in our planetary system completely, when the state of motion of all these bodies at one moment is known?' Kepler's empirical laws of planetary movement, deduced from Tycho Brahe's observations, confronted him, and demanded explanation. These laws gave, it is true, a

* To-day everybody knows what prodigious industry was needed to discover these laws from the empirically ascertained orbits. But few pause to reflect on the brilliant methods by which Kepler deduced the real orbits from the apparent ones—the from the movements as they were observed from the earth.

complete answer to the question of *how* the planets move round the sun (the elliptical shape of the orbit, equal areas in equal times, the relation between the major axes and the period of circulation round the sun), but they did not satisfy the demand for causality. They are three logically independent rules, revealing no inner connection with each other. The third law cannot simply be transferred quantitatively to other central bodies than the sun (there is, for example, no relation between the rotatory period of a planet round the sun and that of a moon round its planet). The most important point, however, is this: these laws are concerned with the movement as a whole, and not with the question *how the state of motion of a system gives rise to that which immediately follows it in time*, they are, as we should say now, integral and not differential laws.

The differential law is the only form which completely satisfies the modern physicist's demand for causality. The clear conception of the differential law is one of Newton's greatest intellectual achievements. It was not merely the notion that was needed but also a mathematical formalism which existed in its rudiments but had to acquire a systematic form. Newton found this also in the differential and the integral calculus. We need not consider the question here whether Newton hit upon the same mathematical methods independently of Leibnitz or not. In any case it was absolutely necessary for Newton to perfect them, since they alone could provide him with the means of expressing his ideas.

Galileo had already made a considerable advance towards a knowledge of the law of motion. He discovered the law of inertia and the law of bodies falling freely in the gravitational field of the earth, namely,

that a mass, (more accurately, mass-point) which is unaffected by other masses, moves uniformly and in a straight line. The vertical speed of a free body in the gravitational field increases uniformly with the time. It may seem to us to-day to be but a short step from Galileo's discoveries to Newton's law of motion. But it should be observed that both the above statements refer in their form to the motion as a whole, whereas Newton's law of motion provides an answer to the question, How does the state of motion of a mass-point behave in an *infinitely short time* under the influence of an external force? It was only by considering what takes place during an infinitely short time (the differential law) that Newton reached a formula which applies to all motion whatsoever. He took the concept of force from statics, which had already reached a high stage of development. The connection between force and acceleration was only made possible for him by the introduction of the new concept of mass, which was supported, strange to say, by an illusory definition. We are so accustomed to-day to the creation of concepts corresponding to differential quotients that we can hardly grasp now what a remarkable power of abstraction it needed to reach the general differential law by a crossing of two frontiers, in the course of which the concept of mass had in addition to be invented.

But a causal conception of motion was still far from being achieved. For the motion was only determined by the equation of motion in cases where the force was given. Inspired no doubt by the uniformity of planetary motions, Newton conceived the idea that the force operating on a mass was determined by the position of all masses situated at a sufficiently small distance from the mass in question. It was not till this

connection was established that a completely causal conception of motion was achieved. How Newton, starting from Kepler's laws of planetary motion, performed this task for gravitation and so discovered that the kinetic forces acting on the stars and gravity were of the same nature, is well known. It is the combination of the Laws of Motion with the Law of Attraction which constitutes that marvellous edifice of thought which makes it possible to calculate the past and future states of a system from the state obtaining at one particular moment, in so far as the events take place under the influence of the forces of gravity alone. The logical completeness of Newton's conceptual system lay in this, that the only things that figure as causes of the acceleration of the masses of a system are *these masses themselves*.

On the strength of the basis here briefly sketched Newton succeeded in explaining the motions of the planets, moons and comets down to the smallest details, as well as the tides and the precessional movement of the earth—a deductive achievement of unique magnificence. The discovery that the cause of the motions of the heavenly bodies is identical with the gravity with which we are so familiar from everyday life must have been particularly impressive.

But the importance of Newton's achievement was not confined to the fact that it created a workable and logically satisfactory basis for the actual science of mechanics, up to the end of the nineteenth century it formed the programme of every worker in the field of theoretical physics. All physical events were to be traced back to masses which are subject to Newton's laws of motion. The law of force simply had to be widened and adapted to the type of event under con-

sideration. Newton himself tried to apply this scheme to optics, assuming light to consist of inert corpuscles. Even the wave theory of light made use of Newton's law of motion, after it had been applied to the mass of a continuum. Newton's equations of motion were the sole basis of the kinetic theory of heat, which not only prepared people's minds for the discovery of the law of the conservation of energy but also led to a theory of gases which has been confirmed down to the last detail, and a more profound view of the nature of the second law of thermodynamics. The development of electricity and magnetism has proceeded right down to our own day along Newtonian lines (electrical and magnetic substance, forces acting at a distance). Even the revolution in electrodynamics and optics brought about by Faraday and Clerk Maxwell, which formed the first great fundamental advance in theoretical physics since Newton, took place entirely under the ægis of Newton's ideas. Clerk Maxwell, Boltzmann and Lord Kelvin never wearied of tracing the electromagnetic fields and their reciprocal dynamic actions back to the mechanical action of hypothetical continuous media possessing mass. As a result, however, of the hopelessness or at any rate the lack of success of those efforts, a gradual revolution in our fundamental notions has taken place since the end of the nineteenth century; theoretical physics have outgrown the Newtonian frame which gave stability and intellectual guidance to science for nearly two hundred years.

Newton's fundamental principles were so satisfactory from the logical point of view that the impetus to overhaul them could only spring from the imperious demands of empirical fact. Before I go into this I must insist that Newton himself was better aware of

the weaknesses inherent in his intellectual edifice than the generations of scientists which followed him. This fact has always roused my respectful admiration, and I should like, therefore, to dwell on it for a moment

(1) In spite of the fact that Newton's ambition to represent his system as necessarily conditioned by experience and to introduce the smallest possible number of concepts not directly referable to empirical objects is everywhere evident, he sets up the concept of absolute space and absolute time, for which he has often been criticised in recent years. But in this point Newton is particularly consistent. He had realised that observable geometrical magnitudes (distances of material points from one another) and their course in time do not completely characterise motion in its physical aspects. He proves this in the famous experiment with the rotating vessel of water. Therefore, in addition to masses and their temporally variable distances, there must be something else that determines motion. That "something" he takes to be relation to "absolute space." He is aware that space must possess a kind of physical reality if his laws of motion are to have any meaning, a reality of the same sort as material points and the intervals between them.

The clear realisation of this reveals both Newton's wisdom and also a weak side to his theory. For the logical structure of the latter would undoubtedly be more satisfactory without this shadowy concept, in that case only things whose relations to perception are perfectly clear (mass-points, distances) would enter into the laws.

(2) The introduction of forces acting directly and instantaneously at a distance into the representation of the effects of gravity is not in keeping with the character

of most of the processes familiar to us from everyday life. Newton meets this objection by pointing to the fact that his law of reciprocal gravitation is not supposed to be a final explanation but a rule derived by induction from experience.

(3) Newton's doctrine provided no explanation for the highly remarkable fact that the weight and the inertia of a body are determined by the same quantity (its mass). The remarkableness of this fact struck Newton himself.

None of these three points can rank as a logical objection to the theory. In a sense they merely represent unsatisfied desires of the scientific spirit in its struggle for a complete and unitary penetration of natural events by thought.

Newton's doctrine of motion, considered as the key idea of the whole of theoretical physics, received its first shock from Clerk Maxwell's theory of electricity. It became clear that the reciprocal actions between bodies due to electric and magnetic forces were effected, not by forces operating instantaneously at a distance, but by processes which are propagated through space at a finite speed. Faraday conceived a new sort of real physical entity, namely the "field," in addition to the mass-point and its motion. At first people tried, clinging to the mechanical mode of thought, to look upon it as a mechanical condition (motion or force) of a hypothetical medium by which space was filled up (the ether). But when this interpretation refused to work in spite of the most obstinate efforts, people gradually got used to the idea of regarding the "electromagnetic field" as a final irreducible constituent of physical reality. We have H. Hertz to thank for definitely freeing the conception of the field from all

encumbrances derived from the conceptual armoury of mechanics, and H. A. Lorentz for freeing it from a material substratum; according to the latter the only thing left to act as a substratum for the field was physical empty space (or ether), which even in the mechanics of Newton had not been destitute of all physical functions. By the time this point was reached, nobody any longer believed in immediate momentary action at a distance, not even in the sphere of gravitation, even though no field-theory of the latter had been clearly sketched out owing to lack of sufficient factual knowledge. The development of the theory of the electro-magnetic field—once Newton's hypothesis of forces acting at a distance had been abandoned—led to the attempt to explain the Newtonian law of motion on electro-magnetic lines or alternatively to replace it by a more accurate one based on the field-theory. Even if these efforts did not meet with complete success, still the fundamental concepts of mechanics had ceased to be looked upon as fundamental constituents of the physical Universe.

The theory of Clerk Maxwell and Lorentz led inevitably to the special theory of relativity, which ruled out the existence of forces acting at a distance, with the resulting destruction of the notion of absolute simultaneity. This theory made it clear that mass is not a constant quantity but depends on the energy-content—is indeed equivalent to it. It also showed that Newton's law of motion was only to be regarded as a limiting law valid for small velocities; in its place it put a new law of motion in which the speed of light in vacuo figures as the critical velocity.

The general theory of relativity formed the last step in the development of the programme of the field-

theory. Quantitatively it modified Newton's theory only slightly, but all the more profoundly for that qualitatively. Inertia, gravitation, and the metrical behaviour of bodies and clocks were reduced to a single field quality, this field itself was again placed in dependence on the bodies (generalisation of Newton's law of gravity or the field-law corresponding to it, as formulated by Poisson). Space and time were thereby divested not of their reality but of their causal absoluteness (absoluteness affecting but not affected) which Newton had been compelled to ascribe to them in order to be able to give expression to the laws then known. The generalised law of inertia takes over the function of Newton's law of motion. This short account is enough to show how the elements of the Newtonian theory passed over into the general theory of relativity, whereby the three defects above mentioned were overcome. It looks as if the law of motion could be deduced from the field-law corresponding to the Newtonian law of force. Only when this goal has been completely reached will it be possible to talk about a pure field-theory.

In a more formal sense also Newton's mechanics prepared the way for the field-theory. The application of Newton's mechanics to continuously distributed masses led inevitably to the discovery and application of partial differential equations, which in their turn first provided the language for the laws of the field-theory. In this formal respect Newton's conception of the differential law constitutes the first decisive step in the development which followed.

The whole evolution of our ideas about the processes of nature, with which we have been concerned so far, might be regarded as an organic development of Newton's ideas. But while the process of perfecting

the field-theory was still in full swing, the facts of heat-radiation, the spectra, radio-activity etc., revealed a limit to the serviceableness of the whole intellectual system which to-day still seems to us absolutely insuperable in spite of immense successes at certain points. Many physicists maintain—and there are weighty arguments in their favour—that in the face of these facts not merely the differential law but the law of causation itself—hitherto the fundamental postulate of all natural science—has collapsed. Even the possibility of a spatio-temporal construction, which can be unambiguously co-ordinated with physical events, is denied. That a mechanical system is permanently susceptible only of discrete energy-values or states—as experience, so to speak, directly shows—seems at first sight hardly deducible from a field-theory which operates with differential equations. The De Broglie-Schrödinger method, which has in a certain sense the character of a field-theory, does indeed deduce the discreteness of energy states, in astonishing agreement with empirical fact, on the basis of differential equations operating with a kind of resonance-theory, but it has to do without a localisation of the mass-particles and without strictly causal laws. Who would presume to-day to decide the question whether the law of causation and the differential law, these ultimate premisses of the Newtonian view of nature, must definitely be given up?

Clerk Maxwell's Influence on the Evolution of the Idea of Physical Reality

The belief in an external world independent of the perceiving subject is the basis of all natural science. Since,

however, sense perception only gives information of this external world or of "physical reality" indirectly, we can only grasp the latter by speculative means. It follows from this that our notions of physical reality can never be final. We must always be ready to change these notions—that is to say, the axiomatic substructure of physics—in order to do justice to perceived facts in the most logically perfect way. Actually a glance at the development of physics shows that it has undergone far-reaching changes in the course of time.

The greatest change in the axiomatic substructure of physics—in other words, of our conception of the structure of reality—since Newton laid the foundation of theoretical physics was brought about by Faraday's and Clerk Maxwell's work on electro-magnetic phenomena. We will try in what follows to make this clearer, keeping both earlier and later developments in sight.

According to Newton's system, physical reality is characterised by the concepts of time, space, material point, and force (=reciprocal action of material points). Physical events, in Newton's view, are to be regarded as the motions, governed by fixed laws, of material points in space. The material point is our only mode of representing reality, when dealing with changes taking place in it. Perceptible bodies are obviously responsible for the concept of the material point; people conceived it as an analogue of mobile bodies, stripping these of the characteristics of extension, form, orientation in space, and all "inward" qualities, leaving only inertia and ~~translation~~ and adding the concept of force. The material bodies, which had led psychologically to our formation of the concept of the "material point," had now themselves to be regarded as systems of material

points. It should be noted that this theoretical scheme is in essence an atomistic and mechanistic one. All happenings were to be interpreted purely mechanically—that is to say, simply as motions of material points according to Newton's law of motion.

The most unsatisfactory side of this system (apart from the difficulties involved in the concept of "absolute space" which have been raised once more just recently) lay in its description of light, which Newton also conceived, in accordance with his system, as composed of material points. Even at that time the question, What in that case becomes of the material points of which light is composed, when the light is absorbed? was already a burning one. Moreover, it is unsatisfactory in any case to introduce into the discussion material points of quite a different sort, which have to be postulated for the purpose of representing ponderable matter and light respectively. Later on corpuscles of electricity were added to these, making a third kind, again with completely different characteristics. It was further, a fundamental weakness that the forces of reciprocal action, by which events are determined, had to be assumed hypothetically in a perfectly arbitrary way. Yet this conception of the real accomplished much: how came it that people felt themselves impelled to forsake it?

In order to put his system into mathematical form at all, Newton had to devise the concept of differential quotients and propound the laws of motion in the form of total differential equations—perhaps the greatest advance in thought that a single individual was ever privileged to make. Partial differential equations were not necessary for this purpose, nor did Newton make any systematic use of them, but they were necessary for the formulation of the mechanics of deformable bodies,

this is connected with the fact that in these problems the question of *how* bodies are supposed to be constructed out of material points was of no importance to begin with

Thus the partial differential equation entered theoretical physics as a handmaid, but has gradually become mistress. This began in the nineteenth century when the wave-theory of light established itself under the pressure of observed fact. Light in empty space was explained as a matter of vibrations of the ether, and it seemed idle at that stage, of course, to look upon the latter as a conglomeration of material points. Here for the first time the partial differential equation appeared as the natural expression of the primary realities of physics. In a particular department of theoretical physics the continuous field thus appeared side by side with the material point as the representative of physical reality. This dualism remains even to-day, disturbing as it must be to every orderly mind.

If the idea of physical reality had ceased to be purely atomic, it still remained for the time being purely *mechanistic*, people still tried to explain all events in terms of the motion of inert masses, indeed no other way of looking at things seemed conceivable. Then came the great change, which will be associated for all time with the names of Faraday, Clerk Maxwell, and Hertz. The lion's share in this revolution fell to Clerk Maxwell. He showed that the whole of what was then known about light and electro-magnetic phenomena was expressed in his well-known double system of differential equations, in which the electric and the magnetic fields appear as the dependent variables. Maxwell did, indeed, try to explain, or justify, these equations by intellectual constructions.

But he made use of several such constructions at the same time and took none of them really seriously, so that the equations alone appeared as the essential thing and the strength of the fields as the ultimate entities, not to be reduced to anything else. By the turn of the century the conception of the electro-magnetic field as an ultimate entity had been generally accepted and serious thinkers had abandoned the belief in the justification, or the possibility, of a mechanical explanation of Clerk Maxwell's equations. Before long they were, on the contrary, actually trying to explain material points and their inertia on field-theory lines with the help of Maxwell's theory, an attempt which did not, however, meet with complete success.

Neglecting the important *individual* results which Clerk Maxwell's life-work produced in several main departments of physics, and concentrating on the changes wrought by him in our conception of the nature of physical reality, we may say this—Before Clerk Maxwell physical reality was conceived—in so far as it was intended to represent events in nature—as made up of material points, whose changes consist exclusively of motions which are subject to partial differential equations. After Maxwell they conceived physical reality as represented by continuous fields, not mechanically explicable, which are subject to partial differential equations. This change in the conception of reality is the most profound and fruitful one that has come to physics since Newton, but it has at the same time to be admitted that the programme has not yet been completely carried out by any means. The successful systems of physics which have been evolved since rather represent compromises between these two schemes, which for that very reason bear a provisional, logically incomplete

character, although they may have achieved great advances in certain particulars.

The first of these that calls for mention is Lorentz's theory of electrons, in which the field and the electrical corpuscles appear side by side as elements of equal value for the comprehension of reality. Next come the special and general theories of relativity, which, though based entirely on ideas connected with the field-theory, have so far been unable to avoid the independent introduction of material points and total differential equations.

The last and most successful creation of theoretical physics, namely quantum-mechanics, differs fundamentally from both the schemes which we will for the sake of brevity call the Newtonian and the Maxwellian. For the quantities which figure in its laws make no claim to describe physical reality itself, but only the *probabilities* of the occurrence of a physical reality that we have in view. Dirac, to whom, in my opinion, we owe the most logically complete exposition of this theory, rightly points out that it would probably be difficult, for example, to give a theoretical description of a photon such as would give enough information to enable one to decide whether it will pass a polariser placed (obliquely) in its way or not.

I am still inclined to the view that physicists will not in the long run content themselves with that sort of indirect description of the real, even if the theory can eventually be adapted to the postulate of general relativity in a satisfactory manner. We shall then, I feel sure, have to return to the attempt to carry out the programme which may properly be described as the Maxwellian—namely, the description of physical reality in terms of fields which satisfy partial differential equations without singularities

Niels Bohr

When a later generation comes to write the history of the progress made in physics in our time, it will have to connect one of the most important advances ever made in our knowledge of the nature of the atom with the name of Niels Bohr. It was already known that classical mechanics break down in relation to the ultimate constituents of matter, also that atoms consist of positively charged nuclei which are surrounded by a layer of atoms of relatively loose texture. But the structure of the spectra, which was to a large extent known empirically, was so profoundly different from what was to be expected on our older theories that nobody could find a convincing theoretical interpretation of the observed uniformities. Thereupon Bohr in the year 1913 devised an interpretation of the simplest spectra on quantum-theory lines, for which he in a short time produced such a mass of quantitative confirmation that the boldly selected hypothetical basis of his speculations soon became a mainstay for the physics of the atom. Although less than ten years have passed since Bohr's first discovery, the system conceived in its main features and largely worked out by him already dominates both physics and chemistry so completely that all earlier systems seem to the expert to date from a long-vanished age. The theories of X-ray spectra, of visible spectra, and of the periodic system of the elements are primarily based on the ideas of Bohr. What is so marvellously attractive about Bohr as a scientific thinker is his rare blend of boldness and caution, seldom has anyone possessed such an intuitive grasp of hidden things combined with such a strong critical sense. With all his knowledge of the details, his eye is immovably

fixed on the underlying principle. He is unquestionably one of the greatest discoverers of our age in the scientific field.

On the Theory of Relativity

An Address in London

It is a particular pleasure to me to have the privilege of speaking in the capital of the country from which the most important fundamental notions of theoretical physics have issued. I am thinking of the theory of mass motion and gravitation which Newton gave us and of the concept of the electro-magnetic field, by means of which Faraday and Clerk Maxwell put physics on a new basis. The theory of relativity may indeed be said to have put a sort of finishing touch to the mighty intellectual edifice of Maxwell and Lorentz, inasmuch as it seeks to extend field-physics to all phenomena, gravitation included.

Turning to the theory of relativity itself, I am anxious to draw attention to the fact that this theory is not speculative in origin, it owes its invention entirely to the desire to make physical theory fit observed fact as well as possible. We have here no revolutionary act but the natural continuation of a line that can be traced through centuries. The abandonment of a certain concept connected with space, time and motion hitherto treated as fundamental must not be regarded as arbitrary but only as conditioned by observed facts.

The law of the constant velocity of light in empty space, which has been confirmed by the development of electro-dynamics and optics, and that of the equal legitimacy of all inertial systems (special principle of relativity), which was proved in a particularly incisive

manner by Michelson's famous experiment, between them made it necessary, in the first place, that the concept of time should be made relative, each inertial system being given its own special time. As this notion was developed it became clear that the connection between immediate experience on one side and co-ordinates and time on the other had hitherto not been thought out with sufficient precision. It is in general one of the essential features of the theory of relativity that it is at pains to work out the relations between general concepts and empirical facts more precisely. The fundamental principle here is that the justification for a physical concept lies exclusively in its clear and unambiguous relation to facts that can be experienced.

According to the special theory of relativity, spatial co-ordinates and time still have an absolute character in so far as they are directly measurable by stationary clocks and bodies. But they are relative in so far as they depend on the state of motion of the selected inertial system. According to the special theory of relativity the four-dimensional continuum formed by the union of space and time retains the absolute character which according to the earlier theory, belonged to both space and time separately (Minkowski). The influence of motion (relative to the co-ordinate system) on the form of bodies and on the motion of clocks, also the equivalence of energy and inert mass follow from the interpretation of co-ordinates and time as products of measurement.

The general theory of relativity owes its existence in the first place to the empirical fact of the numerical equality of the inertial and gravitational mass of bodies for which fundamental fact classical mechanics provided no interpretation. Such an interpretation is arrived at

by an extension of the principle of relativity to co-ordinate systems accelerated relatively to one another. The introduction of co-ordinate systems accelerated relatively to inertial systems involves the appearance of gravitational fields relative to the latter. As a result of this, the general theory of relativity, which is based on the equality of inertia and weight, provides a theory of the gravitational field.

The introduction of co-ordinate systems accelerated relatively to each other as equally legitimate systems, such as they appear conditioned by the identity of inertia and weight, leads, in conjunction with the results of the special theory of relativity, to the conclusion that the laws governing the occupation of space by solid bodies, when gravitational fields are present, do not correspond to the laws of Euclidean geometry. An analogous result follows from the motion of clocks. This brings us to the necessity for yet another generalisation of the theory of space and time, because the direct interpretation of space and time co-ordinates by means of measurements obtainable with measuring rods and clocks now breaks down. That generalisation of metric, which had already been accomplished in the sphere of pure mathematics by the researches of Gauss and Riemann, is essentially based on the fact that the metric of the special theory of relativity can still claim validity for small areas in the general case too.

The process of development here sketched strips the space-time co-ordinates of all independent reality. The metrically real is now only given through the combination of the space-time co-ordinates with the mathematical quantities which describe the gravitational field.

There is yet another factor underlying the evolution of the general theory of relativity. As Ernst Mach

insistently pointed out, the Newtonian theory is unsatisfactory in the following respect—If one considers motion from the purely descriptive, not from the causal, point of view, it only exists as relative motion of things with respect to one another. But the acceleration which figures in Newton's equations of motion is unintelligible if one starts with the concept of relative motion. It compelled Newton to invent a physical space in relation to which acceleration was supposed to exist. This introduction *ad hoc* of the concept of absolute space, while logically unexceptionable, nevertheless seems unsatisfactory. Hence the attempt to alter the mechanical equations in such a way that the inertia of bodies is traced back to relative motion on their part not as against absolute space but as against the totality of other ponderable bodies. In the state of knowledge then existing his attempt was bound to fail.

The posing of the problem seems, however, entirely reasonable. This line of argument imposes itself with considerably enhanced force in relation to the general theory of relativity, since, according to that theory, the physical properties of space are affected by ponderable matter. In my opinion, the general theory of relativity can only solve this problem satisfactorily if it regards the world as spatially self-enclosed. The mathematical results of the theory force one to this view, if one believes that the mean density of ponderable matter in the world possesses some ultimate value, however small.

What is the Theory of Relativity?

I gladly accede to the request of your colleague to write something for *The Times* on relativity. After the lamentable breakdown of the old active intercourse

ulated criteria which the separate processes or the theoretical representations of them have to satisfy. Thus the science of thermodynamics seeks by analytical means to deduce necessary connections, which separate events have to satisfy, from the universally experienced fact that perpetual motion is impossible.

The advantages of the constructive theory are completeness, adaptability and clearness, those of the principle-theory are logical perfection and security of the foundations.

The theory of relativity belongs to the latter class. In order to grasp its nature, one needs first of all to become acquainted with the principles on which it is based. Before I go into these, however, I must observe that the theory of relativity resembles a building consisting of two separate storeys, the special theory and the general theory. The special theory, on which the general theory rests, applies to all physical phenomena with the exception of gravitation, the general theory provides the law of gravitation and its relations to the other forces of nature.

It has, of course, been known since the days of the ancient Greeks that in order to describe the movement of a body, a second body is needed to which the movement of the first is referred. The movement of a vehicle is considered in reference to the earth's surface, that of a planet to the totality of the visible fixed stars. In physics the body to which events are spatially referred is called the co-ordinate system. The laws of the mechanics of Galileo and Newton, for instance, can only be formulated with the aid of a co-ordinate system.

The state of motion of the co-ordinate system may not, however, be arbitrarily chosen, if the laws of mechanics are to be valid (it must be free from rotation and accelera-

tion) A co-ordinate system which is admitted in mechanics is called an "inertial system". The state of motion of an inertial system is according to mechanics not one that is determined unambiguously by nature. On the contrary, the following definition holds good — a co-ordinate system that is moving uniformly and in a straight line relatively to an inertial system is likewise an inertial system. By the "special principle of relativity" is meant the generalisation of this definition to include any natural event whatever: thus, every universal law of nature which is valid in relation to a co-ordinate system C , must also be valid, as it stands, in relation to a co-ordinate system C' , which is in uniform translatory motion relatively to C .

The second principle, on which the special theory of relativity rests, is the "principle of the constant velocity of light in vacuo". This principle asserts that light in vacuo always has a definite velocity of propagation, independent of the state of motion of the observer or of the source of light. The confidence which physicists place in this principle springs from the successes achieved by the electro-dynamics of Clerk Maxwell and Lorentz.

Both the above-mentioned principles are powerfully supported by experience, but appear not to be logically reconcilable. The special theory of relativity finally succeeded in reconciling them logically by a modification of kinematics—i.e., of the doctrine of the laws relating to space and time (from the point of view of physics). It became clear that to speak of the simultaneity of two events had no meaning except in relation to a given co-ordinate system, and that the shape of measuring devices and the speed at which clocks move depend on their state of motion with respect to the co-ordinate system.

inertia of a body are controlled by the same constant (Equality of inertial and gravitational mass) Imagine a co-ordinate system which is rotating uniformly with respect to an inertial system in the Newtonian manner. The centrifugal forces which manifest themselves in relation to this system must, according to Newton's teaching, be regarded as effects of inertia. But these centrifugal forces are, exactly like the forces of gravity, proportional to the masses of the bodies. Ought it not to be possible in this case to regard the co-ordinate system as stationary and the centrifugal forces as gravitational forces? This seems the obvious view, but classical mechanics forbid it.

This hasty consideration suggests that a general theory of relativity must supply the laws of gravitation, and the consistent following-up of the idea has justified our hopes.

But the path was thornier than one might suppose, because it demanded the abandonment of Euclidean geometry. That is to say, the laws according to which fixed bodies may be arranged in space do not completely accord with the spatial laws attributed to bodies by Euclidean geometry. This is what we mean when we talk of the "curvature of space." The fundamental concepts of the "straight line," the "plane" etc. thereby lose their precise significance in physics.

In the general theory of relativity the doctrine of space and time, or kinematics, no longer figures as a fundamental independent of the rest of physics. The geometrical behaviour of bodies and the motion of clocks rather depend on gravitational fields, which in their turn are produced by matter.

The new theory of gravitation diverges considerably, as regards principles, from Newton's theory. But its

practical results agree so nearly with those of Newton's theory that it is difficult to find criteria for distinguishing them which are accessible to experience. Such have been discovered so far —

(1) In the revolution of the ellipses of the planetary orbits round the sun (confirmed in the case of Mercury)

(2) In the curving of light rays by the action of gravitational fields (confirmed by the English photographs of eclipses)

(3) In a displacement of the spectral lines towards the red end of the spectrum in the case of light transmitted to us from stars of considerable magnitude (unconfirmed so far) ¹

The chief attraction of the theory lies in its logical completeness. If a single one of the conclusions drawn from it proves wrong, it must be given up, to modify it without destroying the whole structure seems to be impossible.

Let no one suppose, however, that the mighty work of Newton can really be superseded by this or any other theory. His great and lucid ideas will retain their unique significance for all time as the foundation of our whole modern conceptual structure in the sphere of natural philosophy.

ADDENDUM Some of the statements in your paper concerning my life and person owe their origin to the lively imagination of the writer. Here is yet another application of the principle of relativity for the delectation of the reader — To-day I am described in Germany as a "German savant," and in England as a "Swiss Jew." Should it ever be my fate to be represented as a *bête noire*, I should, on the contrary, become a "Swiss Jew."

¹ Editor's Note. This criterion has also been confirmed in the meantime.

for the Germans and a "German savant" for the English

The Problem of Space, Ether, and the Field in Physics

Scientific thought is a development of pre-scientific thought. As the concept of space was already fundamental in the latter, we must begin with the concept of space in pre-scientific thought. There are two ways of regarding concepts, both of which are necessary to understanding. The first is that of logical analysis. It answers the question, How do concepts and judgments depend on each other? In answering it we are on comparatively safe ground. It is the security by which we are so much impressed in mathematics. But this security is purchased at the price of emptiness of content. Concepts can only acquire content when they are connected, however indirectly, with sensible experience. But no logical investigation can reveal this connection, it can only be experienced. And yet it is this connection that determines the cognitive value of systems of concepts.

Take an example. Suppose an archaeologist belonging to a later culture finds a text-book of Euclidean geometry without diagrams. He will discover how the words "point," "straight line," "plane," are used in the propositions. He will also see how the latter are deduced from each other. He will even be able to frame new propositions according to the known rules. But the framing of these propositions will remain an empty word-game for him, as long as "point," "straight line," "plane" etc. "convey nothing" to him. Only when they do convey something will geometry possess any real content for him. The same will be true of analytical

Now as regards the concept of space. this seems to presuppose the concept of the solid object. The nature of the complexes and sense-impressions which are probably responsible for that concept has oft-n been described. The correspondence between certain visual and tactile impressions, the fact that they can be continuously followed out through time, and that the impressions can be repeated at any moment (taste, sight), are some of those characteristics. Once the concept of the solid object is formed in connection with the experiences just mentioned—which concept by no means presupposes that of space or spatial relation—the desire to get an intellectual grasp of the relations of such solid bodies is bound to give rise to concepts which correspond to their spatial relations. Two solid objects may touch one another or be distant from one another. In the latter case, a third body can be inserted between them without altering them in any way, in the former not. These spatial relations are obviously real in the same sense as the bodies themselves. If two bodies are of equal value for the filling of *one* such interval, they will also prove of equal value for the filling of other intervals. The interval is thus shown to be independent of the selection of any special body to fill it, the same is universally true of spatial relations. It is plain that this independence, which is a principal condition of the usefulness of framing purely geometrical concepts, is not necessarily *a priori*. In my opinion, this concept of the interval, detached as it is from the selection of any special body to occupy it, is the starting-point of the whole concept of space.

Considered, then, from the point of view of sense experience, the development of the concept of space seems, after these brief indications, to conform to the

mechanics, and indeed of any exposition of the logically deductive sciences.

What does this talk of "straight line," "point," "intersection" etc. "conveying something to one" mean? It means that one can point to the parts of sensible experience to which those words refer. This extra-logical problem is the essential problem, which the archæologist will only be able to solve intuitively, by examining his experience and seeing if he can discover anything which corresponds to those primary terms of the theory and the axioms laid down for them. Only in this sense can the question of the nature of a conceptually presented entity be reasonably raised.

With our pre-scientific concepts we are very much in the position of our archæologist in regard to the ontological problem. We have, so to speak, forgotten what features in the world of experience caused us to frame those concepts, and we have great difficulty in representing the world of experience to ourselves without the spectacles of the old-established conceptual interpretation. There is the further difficulty that our language is compelled to work with words which are inseparably connected with those primitive concepts. These are the obstacles which confront us when we try to describe the essential nature of the pre-scientific concept of space.

One remark about concepts in general, before we turn to the problem of space: concepts have reference to sensible experience, but they are never, in a logical sense, deducible from them. For this reason I have never been able to understand the quest of the *a priori* in the Kantian sense. In any ontological question, the only possible procedure is to seek out those characteristics in the complex of sense experiences to which the concepts refer.

Now as regards the concept of space this seems to presuppose the concept of the solid object. The nature of the complexes and sense-impressions which are probably responsible for that concept has often been described. The correspondence between certain visual and tactile impressions, the fact that they can be continuously followed out through time, and that the impressions can be repeated at any moment (taste, sight), are some of those characteristics. Once the concept of the solid object is formed in connection with the experiences just mentioned—which concept by no means presupposes that of space or spatial relation—the desire to get an intellectual grasp of the relations of such solid bodies is bound to give rise to concepts which correspond to their spatial relations. Two solid objects may touch one another or be distant from one another. In the latter case, a third body can be inserted between them without altering them in any way, in the former not. These spatial relations are obviously real in the same sense as the bodies themselves. If two bodies are of equal value for the filling of *one* such interval, they will also prove of equal value for the filling of other intervals. The interval is thus shown to be independent of the selection of any special body to fill it, the same is universally true of spatial relations. It is plain that this independence, which is a principal condition of the usefulness of framing purely geometrical concepts, is not necessarily *a priori*. In my opinion, this concept of the interval, detached as it is from the selection of any special body to occupy it, is the starting-point of the whole concept of space.

Considered, then, from the point of view of sense experience, the development of the concept of space seems, after these brief indications, to conform to the

following schema—solid body, spatial relations of solid bodies, interval, space. Looked-at in this way, space appears as something real in the same sense as solid bodies.

It is clear that the concept of space as a real thing already existed in the extra-scientific conceptual world. Euclid's mathematics, however, knew nothing of this concept as such, they confined themselves to the concepts of the object, and the spatial relations between objects. The point, the plane, the straight line, length, are solid objects idealised. All spatial relations are reduced to those of contact (the intersection of straight lines and planes, points lying on straight lines, etc.) Space as a continuum does not figure in the conceptual system at all. This concept was first introduced by Descartes, when he described the point-in-space by its co-ordinates. Here for the first time geometrical figures appear, up to a point, as parts of infinite space, which is conceived as a three-dimensional continuum.

The great superiority of the Cartesian treatment of space is by no means confined to the fact that it applies analysis to the purposes of geometry. The main point seems rather to be this—The geometry of the Greeks prefers certain figures (the straight line, the plane) in geometrical descriptions, other figures (e.g., the ellipse) are only accessible to it because it constructs or defines them with the help of the point, the straight line and the plane. In the Cartesian treatment on the other hand, all surfaces are, in principle, equally represented, without any arbitrary preference for linear figures in the construction of geometry.

In so far as geometry is conceived as the science of laws governing the mutual relations of practically rigid bodies in space, it is to be regarded as the oldest branch

of physics. This science was able, as I have already observed, to dispense with the concept of space as such; the ideal corporeal forms—point, straight line, plane, length—being sufficient for its needs. On the other hand, space as a whole, as conceived by Descartes, was absolutely necessary to Newtonian physics. For dynamics cannot manage with the concepts of the mass-point and the (temporally variable) distance between mass-points, alone. In Newton's equations of motion the concept of acceleration plays a fundamental part, which cannot be defined by the temporally variable intervals between points alone. Newton's acceleration is only thinkable or definable in relation to space as a whole. Thus to the geometrical reality of the concept of space a new inertia-determining function of space was added. When Newton described space as absolute, he no doubt meant this real significance of space, which made it necessary for him to attribute to it a quite definite state of motion, which yet did not appear to be fully determined by the phenomena of mechanics. This space was conceived as absolute in another sense also; its inertia-determining effect was conceived as autonomous, i.e., not to be influenced by any physical circumstance whatever; it affected masses, but nothing affected it.

And yet in the minds of physicists space remained until the most recent time simply the passive container of all events, playing no part in physical happenings itself. Thought only began to take a new turn with the wave theory of light and the theory of the electromagnetic field of Faraday and Clerk Maxwell. It became clear that there existed in free space conditions which propagated themselves in waves, as well as localised fields which were able to exert force on elec-

trical masses or magnetic poles brought to the spot. Since it would have seemed utterly absurd to the physicists of the nineteenth century to attribute physical functions or states to space itself, they invented a medium pervading the whole of space, on the model of ponderable matter—the ether, which was supposed to act as a vehicle for electro-magnetic phenomena, and hence for those of light also. The states of this medium, imagined as constituting the electro-magnetic fields, were at first thought of mechanically, on the model of the elastic deformations of rigid bodies. But this mechanical theory of the ether was never quite successful, and so the idea of a closer explanation of the nature of the *etheric* fields was given up. The ether thus became a kind of matter whose only function was to act as a substratum for electrical fields which were by their very nature not further analysable. The picture was, then, as follows — Space is filled by the ether, in which the material corpuscles or atoms of ponderable matter swim, the atomic structure of the latter had been securely established by the turn of the century.

Since the reciprocal action of bodies was supposed to be accomplished through fields, there had also to be a gravitational field in the ether, whose field-law had, however, assumed no clear form at that time. The ether was only accepted as the seat of all operations of force which make themselves effective across space. Since it had been realised that electrical masses in motion produce a magnetic field, whose energy acted as a model for inertia, inertia also appeared as a field-action localised in the ether.

The mechanical properties of the ether were at first a mystery. Then came H. A. Lorentz's great discovery. All the phenomena of electro-magnetism then known

could be explained on the basis of two assumptions—that the ether is firmly fixed in space—that is to say, unable to move at all, and that electricity is firmly lodged in the mobile elementary particles. To-day his discovery may be expressed as follows—Physical space and the ether are only different terms for the same thing, fields are physical conditions of space. For if no particular state of motion can be ascribed to the ether, there does not seem to be any ground for introducing it as an entity of a special sort alongside of space. But the physicists were still far removed from such a way of thinking, space was still, for them, a rigid, homogeneous something, susceptible of no change or conditions. Only the genius of Riemann, solitary and uncomprehended, had already won its way by the middle of last century to a new conception of space, in which it was deprived of its rigidity and its power to take part in physical events recognised as possible. This intellectual achievement commands our admiration all the more for having preceded Faraday's and Clerk Maxwell's field-theory of electricity. Then came the special theory of relativity with its recognition of the physical equivalence of all inertial systems. The inseparableness of time and space emerged in connection with electrodynamics, or the law of the propagation of light. Hitherto it had been silently assumed that the four-dimensional continuum of events could be split up into time and space in an objective manner—i.e., that an absolute significance attached to the "now" in the world of events. With the discovery of the relativity of simultaneity, space and time were merged in a single continuum in the same way as the three dimensions of space had been before. Physical space was thus increased to a four-dimensional space which also included

the dimension of time. The four-dimensional space of the special theory of relativity is just as rigid and absolute as Newton's space.

The theory of relativity admirably exemplifies the fundamental character of the modern development of theoretical science. The hypotheses with which it starts become steadily more abstract and remote from experience. On the other hand it gets nearer to the grand aim of all science, which is to cover the greatest possible number of empirical facts by logical deduction from the smallest possible number of hypotheses or axioms. Meanwhile the train of thought leading from the axioms to the empirical facts or verifiable consequences gets steadily longer and more subtle. The theoretical scientist is compelled in an increasing degree to be guided by purely mathematical, formal considerations in his search for a theory, because the physical experience of the experimenter cannot lift him into the regions of highest abstraction. The predominantly inductive methods appropriate to the youth of science are giving place to tentative deduction. Such a theoretical structure needs to be very thoroughly elaborated before it can lead to conclusions which can be compared with experience. Here, too, the observed fact is undoubtedly the supreme arbiter, but it cannot pronounce sentence until the wide chasm separating the axioms from their verifiable consequences has been bridged by much intense hard thinking. The theorist has to set about this Herculean task in the clear consciousness that his efforts may only be destined to deal the death-blow to his theory. The theorist who undertakes such a labour should not be carped at as *fanciful*, on the contrary, he should be encouraged to give free reign to his fancy for there is no other way to the goal. His is no idle day-

dreaming, but a search for the logically simplest possibilities and their consequences. This plea was needed in order to make the hearer or reader more ready to follow the ensuing train of ideas with attention, it is the line of thought which has led from the special to the general theory of relativity and thence to its latest offshoot, the unitary field-theory. In this exposition the use of mathematical symbols cannot be avoided.

We start with the special theory of relativity. This theory is still based directly on an empirical law, that of the constant velocity of light. Let P be a point in empty space, P' one separated from it by a length ds and infinitely near to it. Let a flash of light be emitted from P at a time t and reach P' at a time $t + dt$. Then

$$ds^2 = c^2 dt^2$$

If dx_1, dx_2, dx_3 are the orthogonal projections of ds , and the imaginary time co-ordinate $\sqrt{-1} ct = x_4$ is introduced, then the above-mentioned law of the constancy of the propagation of light takes the form

$$ds^2 = dx_1^2 + dx_2^2 + dx_3^2 + dx_4^2 = 0$$

Since this formula expresses a real situation, we may attribute a real meaning to the quantity ds even supposing the neighbouring points of the four-dimensional continuum are selected in such a way that the ds belonging to them does not disappear. This is more or less expressed by saying that the four-dimensional space (with imaginary time-co-ordinates) of the special theory of relativity possesses a Euclidean metric.

The fact that such a metric is called Euclidean is connected with the following. The positing of such a metric in a three-dimensional continuum is fully equivalent to the positing of the axioms of Euclidean geometry. The defining equation of the metric is thus

nothing but the Pythagorean theorem applied to the differentials of the co-ordinates

Such alteration of the co-ordinates (by transformation) is permitted in the special theory of relativity, since in the new co-ordinates too the magnitude ds^2 (fundamental invariant) is expressed in the new differentials of the co-ordinates by the sum of the squares. Such transformations are called Lorentz transformations.

The heuristic method of the special theory of relativity is characterised by the following principle — Only those equations are admissible as an expression of natural laws which do not change their form when the co-ordinates are changed by means of a Lorentz transformation (co-variance of equations in relation to Lorentz transformations).

This method led to the discovery of the necessary connection between impulse and energy, the strength of an electric and a magnetic field, electrostatic and electro-dynamic forces, inert mass and energy, and the number of independent concepts and fundamental equations was thereby reduced.

This method pointed beyond itself. Is it true that the equations which express natural laws are co-variant in relation to Lorentz transformations only, and not in relation to other transformations? Well formulated in that way the question really means nothing, since every system of equations can be expressed in general co-ordinates. We must ask, Are not the laws of nature so constituted that they receive no real simplification through the choice of any one particular set of co-ordinates?

We will only mention in passing that our empirical principle of the equality of inert and heavy masses prompts us to answer this question in the affirmative.

If we elevate the equivalence of all co-ordinate systems for the formulation of natural laws into a principle, we arrive at the general theory of relativity, provided we stick to the law of the constant velocity of light or to the hypothesis of the objective significance of the Euclidean metric at least for infinitely small portions of four-dimensional space

This means that for finite regions of space the existence (significant for physics) of a general Riemannian metric is presupposed according to the formula

$$ds^2 = \sum_{\mu\nu} g_{\mu\nu} dx^\mu dx^\nu,$$

whereby the summation is to be extended to all index combinations from 11 to 44

The structure of such a space differs absolutely radically in one respect from that of a Euclidean space. The coefficients $g_{\mu\nu}$ are for the time being any functions whatever of the co-ordinates x_1 to x_4 , and the structure of the space is not really determined until these functions $g_{\mu\nu}$ are really known. It is only determined more closely by specifying laws which the metrical field of the $g_{\mu\nu}$ satisfies. On physical grounds this gave rise to the conviction that the metrical field was at the same time the gravitational field.

Since the gravitational field is determined by the configuration of masses and changes with it, the geometric structure of this space is also dependent on physical factors. Thus according to this theory space is—exactly as Riemann guessed—no longer absolute, its structure depends on physical influences. Physical geometry is no longer an isolated self-contained science like the geometry of Euclid.

The problem of gravitation was thus reduced to a

mathematical problem it was required to find the simplest fundamental equations which are co-variant in relation to any transformation of co-ordinates whatever.

I will not speak here of the way this theory has been confirmed by experience, but explain at once why Theory could not rest permanently satisfied with this success. Gravitation had indeed been traced to the structure of space, but besides the gravitational field there is also the electro-magnetic field. This had, to begin with, to be introduced into the theory as an entity independent of gravitation. Additional terms which took account of the existence of the electro-magnetic field had to be included in the fundamental equations for the field. But the idea that there were two structures of space independent of each other, the metric-gravitational and the electro-magnetic, was intolerable to the theoretical spirit. We are forced to the belief that both sorts of field must correspond to a unified structure of space.

The "unitary field-theory," which represents itself as a mathematically independent extension of the general theory of relativity, attempts to fulfil this last postulate of the field theory. The formal problem should be put as follows:—Is there a theory of the continuum in which a new structural element appears side by side with the metric such that it forms a single whole together with the metric? If so, what are the simplest field-laws to which such a continuum can be made subject? And finally, are these field-laws well fitted to represent the properties of the gravitational field and the electro-magnetic field? Then there is the further question whether the corpuscles (electrons and protons) can be regarded as locations of particularly dense fields, whose movements are determined by the field equations. At

present there is only one way of answering the first three questions. The space structure on which it is based may be described as follows, and the description applies equally to a space of any number of dimensions.

Space has a Riemannian metric. This means that the Euclidean geometry holds good in the infinitesimal neighbourhood of every point P . Thus for the neighbourhood of every point P there is a local Cartesian system of co-ordinates, in reference to which the metric is calculated according to the Pythagorean theorem. If we now imagine the length l cut off from the positive axes of these local systems, we get the orthogonal local unit vector. Such a local unit vector is to be found in every other point P' of space also. Thus, if a linear element (PG or $P'G$) starting from the points P or P' , is given, then the magnitude of this linear element can be calculated by the aid of the relevant local unit vector, from its local co-ordinates by means of Pythagoras's theorem. There is therefore a definite meaning in speaking of the numerical equality of the linear elements PG and $P'G$.

It is essential to observe now that the local orthogonal unit vectors are not completely determined by the metric. For we can still select the orientation of the unit vectors perfectly freely without causing any alteration in the result of calculating the size of the linear elements according to Pythagoras's theorem. A corollary of this is that in a space whose structure consists exclusively of a Riemannian metric, two linear elements PG and $P'G'$ can be compared with regard to their magnitude but not their direction, in particular, there is no sort of point in saying that the two linear elements are parallel to one another. In this respect, therefore, the purely

metrical (Riemannian) space is less rich in structure than the Euclidean

Since we are looking for a space which exceeds Riemannian space in wealth of structure, the obvious thing is to enrich Riemannian space by adding the relation of direction or parallelism. Therefore for every direction through P let there be a definite direction through P' , and let this mutual relation be a determinate one. We call the directions thus related to each other "parallel". Let this parallel relation further fulfil the condition of angular uniformity: if PG and PK are two directions in P , $P'G'$ and $P'K'$ the corresponding parallel directions through P' , then the angles KPG and $K'P'G'$ (measurable on Euclidean lines in the local system) should be equal.

The basic space-structure is thereby completely defined. It is most easily described mathematically as follows:—In the definite point P we suppose an orthogonal unit vector with definite, freely chosen orientation. In every other point P' of space we so orient its local unit vector that its axes are parallel to the corresponding axes at the point P . Given the above structure of space and free choice in the orientation of the unit vector at one point P , all unit vectors are thereby completely defined. In the space P let us now imagine any Gaussian system of co-ordinates and that in every point the axes of the unit vector there are projected on to it. This system of n^2 components completely describes the structure of space.

This spatial structure stands, in a sense, midway between the Riemannian and the Euclidean. In contrast to the former, it has room for the straight line: that is to say a line all of whose elements are parallel to each other in pairs. The geometry here described differs from the

Euclidean in the non-existence of the parallelogram. If at the ends P and G of a length PG two equal and parallel lengths PP' and GG' are marked off, $P'G'$ is in general neither equal nor parallel to PG .

The mathematical problem now solved so far is this — What are the simplest conditions to which a space-structure of the kind described can be subjected? The chief question which still remains to be investigated is this — To what extent can physical fields and primary entities be represented by solutions, free from singularities, of the equations which answer the former question?

Notes on the origin of the general theory of Relativity -

I gladly accede to the request that I should say something about the history of my own scientific work. Not that I have an exaggerated notion of the importance of my own efforts, but to write the history of other men's work demands a degree of absorption in other people's ideas which is much more in the line of the trained historian, to throw light on one's own earlier thinking appears incomparably easier. Here one has an immense pull over everybody else, and one ought not to leave the opportunity unused out of modesty.

When, by the special theory of relativity, I had arrived at the equivalence of all so-called inertial systems for the formulation of natural laws (1905), the question whether there was not a further equivalence of co-ordinate systems followed naturally, to say the least of it. To put it in another way, if only a relative meaning can be attached to the concept of velocity, ought we nevertheless to persevere in treating acceleration as an absolute concept?

From the purely kinematic point of view there was

no doubt about the relativity of all motions whatever, but physically speaking, the inertial system seemed to occupy a privileged position, which made the use of co-ordinate systems moving in other ways appear artificial

I was, of course, acquainted with Mach's view, according to which it appeared conceivable that what inertial resistance counteracts is not acceleration as such but acceleration with respect to the masses of the other bodies existing in the world. There was something fascinating about this idea to me, but it provided no workable basis for a new theory.

I first came a step nearer to the solution of the problem when I attempted to deal with the law of gravity within the framework of the special theory of relativity. Like most writers at the time, I tried to frame a *field-law* for gravitation, since it was no longer possible, at least in any natural way, to introduce direct action at a distance, owing to the abolition of the notion of absolute simultaneity.

The simplest thing was, of course, to retain the Laplacian scalar potential of gravity, and to complete the equation of Poisson in an obvious manner by a term differentiated as to time in such a way that the special theory of relativity was satisfied. The law of motion of the mass point in a gravitational field had also to be adapted to the special theory of relativity. The path was not so unmistakably marked out here, since the inert mass of a body might depend on the gravitational potential. In fact this was to be expected on account of the principle of the inertia of energy.

These investigations, however, led to a result which raised my strong suspicions. According to classical mechanics the vertical acceleration of a body in the

vertical gravitational field is independent of the horizontal component of velocity. Hence in such a gravitational field the vertical acceleration of a mechanical system or of its centre of gravity works out independently of its internal kinetic energy. But in the theory I advanced the acceleration of a falling body was not independent of the horizontal velocity or the internal energy of a system.

This did not fit in with the old experimental fact that all bodies have the same acceleration in a gravitational field. This law, which may also be formulated as the law of the equality of inertial and gravitational mass, was now brought home to me in all its significance. I was in the highest degree amazed at its persistence and guessed that in it must lie the key to a deeper understanding of inertia and gravitation. I had no serious doubts about its strict validity, even without knowing the results of the admirable experiments of Eotvos, which—if my memory is right—I only came to know later.

I now abandoned as inadequate the attempt to treat the problem of gravitation, in the manner outlined above, within the framework of the special theory of relativity. It clearly failed to do justice to the most fundamental property of gravitation. The principle of the equality of inertial and gravitational mass could now be formulated quite clearly as follows—In a homogeneous gravitational field all motions take place in the same way as in the absence of a gravitational field in relation to a uniformly accelerated co-ordinate system. If this principle held good for any events whatever (the "principle of equivalence"), this was an indication that the principle of relativity needed to be extended to co-ordinate systems in non-uniform motion with re-

spect to each other, if we were to reach an easy and natural theory of the gravitational field. Such reflections kept me busy from 1908 to 1911, and I attempted to draw special conclusions from them, of which I do not propose to speak here. For the moment the one important thing was the discovery that a reasonable theory of gravitation could only be hoped-for from an extension of the principle of relativity.

What was needed, therefore, was to frame a theory whose equations kept their form in the case of non-linear transformations of the co-ordinates. Whether this was to apply to absolutely any (constant) transformations of co-ordinates or only to certain ones, I could not for the moment say.

I soon saw that bringing in non-linear transformations, as the principle of equivalence demanded, was inevitably fatal to the simple physical interpretation of the co-ordinates—i.e., that it could no longer be required that differentials of co-ordinates should signify direct results of measurement with ideal scales or clocks. I was much bothered by this piece of knowledge, for it took me a long time to see what co-ordinates in general really meant in physics. I did not find the way out of this dilemma till 1912, and then it came to me as a result of the following consideration—

A new formulation of the law of inertia had to be found which in case of the absence of a real "gravitational field with application of an inertial system" as a co-ordinate system passed over into Galileo's formula for the principle of inertia. The latter amounts to this—A material point, which is acted on by no force, will be represented in four-dimensional space by a straight line, that is to say, by a line that is as short as possible or, more correctly, an extreme line. This concept pre-

supposes that of the length of a linear element, that is to say, a metric. In the special theory of relativity, as Minkowski had shown, this metric was a quasi-Euclidean one, i.e., the square of the "length" ds of the linear element was a definite quadratic function of the differentials of the co-ordinates

If other co-ordinates are introduced by means of a non-linear transformation, ds^2 remains a homogeneous function of the differentials of the co-ordinates, but the coefficients of this function ($g_{\mu\nu}$) cease to be constant and become certain functions of the co-ordinates. In mathematical terms this means that physical (four-dimensional) space has a Riemannian metric. The time-like extremal lines of this metric furnish the law of motion of a material point which is acted on by no force apart from the forces of gravity. The coefficients ($g_{\mu\nu}$) of this metric at the same time describe the gravitational field with reference to the co-ordinate system selected. A natural formulation of the principle of equivalence had thus been found, the extension of which to any gravitational field whatever formed a perfectly natural hypothesis.

The solution of the above-mentioned dilemma was therefore as follows — A physical significance attaches not to the differentials of the co-ordinates but only to the Riemannian metric co-ordinated with them. A workable basis had now been found for the general theory of relativity. Two further problems remained to be solved, however.

(1) If a field-law is given in the terminology of the special theory of relativity, how can it be transferred to the case of a Riemannian metric?

(2) What are the differential laws which determine the Riemannian metric (i.e., $g_{\mu\nu}$) itself?

spect to each other, if we were to reach an easy and natural theory of the gravitational field. Such reflections kept me busy from 1908 to 1911, and I attempted to draw special conclusions from them, of which I do not propose to speak here. For the moment the one important thing was the discovery that a reasonable theory of gravitation could only be hoped-for from an extension of the principle of relativity.

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Relativity and the Ether

Why is it that alongside of the notion, derived by abstraction from everyday life, of ponderable matter physicists have set the notion of the existence of another sort of matter, the ether? The reason lies no doubt in those phenomena which gave rise to the theory of forces acting at a distance, and in those properties of light which led to the wave-theory. Let us shortly consider these two things.

Non-physical thought knows nothing of forces acting at a distance. When we try to explain our experiences of bodies by a complete causal scheme, there seems at first sight to be no reciprocal interaction except what is produced by means of immediate contact, e.g., the transmission of motion by impact, pressure or pull, heating or inducing combustion by means of a flame, etc. To be sure, gravity, that is to say, a force acting at a distance, does play an important part in everyday experience. But since the gravity of bodies presents itself to us in common life as something constant, dependent on no variable temporal or spatial cause, we do not ordinarily think of any cause in connection with it and thus are not conscious of its character as a force acting at a distance. It was not till Newton's theory of gravitation that a cause was assigned to it, it was then explained as a force acting at a distance, due to mass. Newton's theory certainly marks the greatest step ever taken in linking up natural phenomena causally. And yet his contemporaries were by no means satisfied with it, because it seemed to contradict the principle derived from the rest of experience, that reciprocal action only takes place by means of direct contact, not by direct action at a distance, without any means of transmission.

I worked on these problems from 1912 to 1914 together with my friend Grossmann. We found that the mathematical methods for solving problem (1) lay ready to our hands in the infinitesimal differential calculus of Ricci and Levi-Civita.

As for problem (2), its solution obviously needed invariant differential systems of the second order taken from $g_{\mu\nu}$. We soon saw that these had already been established by Riemann (the tensor of curvature). We had already considered the right field-equations for gravitation two years before the publication of the general theory of relativity, but we were unable to see how they could be used in physics. On the contrary, I felt sure that they could not do justice to experience. Moreover I believed that I could show on general considerations that a law of gravitation invariant in relation to any transformation of co-ordinates whatever was inconsistent with the principle of causation. These were errors of thought which cost me two years of excessively hard work, until I finally recognised them as such at the end of 1915 and succeeded in linking up with the facts of astronomical experience, after having ruefully returned to the Riemannian curvature.

In the light of knowledge attained, the happy achievement seems almost a matter of course, and any intelligent student can grasp it without too much trouble. But the years of anxious searching in the dark, with their intense longing, their alternations of confidence and exhaustion, and the final emergence into the light,—only those who have experienced it can understand that.

other beyond the small deformations which correspond to the waves of light

This theory, also called the theory of the stationary luminiferous ether, derived strong support from the experiments, of fundamental importance for the special theory of relativity too, of Fizeau, which proved conclusively that the luminiferous ether does not participate in the motions of bodies. The phenomenon of aberration also lent support to the theory of the quasi-rigid ether.

The evolution of electrical theory along the lines laid down by Clerk Maxwell and Lorentz gave a most peculiar and unexpected turn to the development of our ideas about the ether. For Clerk Maxwell himself the ether was still an entity with purely mechanical properties, though of a far more complicated kind than those of tangible solid bodies. But neither Maxwell nor his successors succeeded in thinking out a mechanical model for the ether capable of providing a satisfactory mechanical interpretation of Maxwell's laws of the electro-dynamic field. The laws were clear and simple, the mechanical interpretations clumsy and contradictory. Almost imperceptibly theoretical physicists adapted themselves to this state of affairs (which was a most depressing one from the point of view of their mechanistic programme) especially under the influence of the electro-dynamic researches of Heinrich Hertz. Whereas they had formerly demanded of an ultimate theory that it should be based upon fundamental concepts of a purely mechanical kind (e.g., mass-densities, velocities, deformations, forces of gravitation), they gradually became accustomed to admitting electric and magnetic field-strength as fundamental concepts alongside of the mechanical ones, without insisting upon a mechanical

Man's thirst for knowledge only acquiesces in such a dualism reluctantly. How could unity in our conception of natural forces be saved? People could either attempt to treat the forces which appear to us to act by contact as acting at a distance, though only making themselves felt at very small distances, this was the way generally chosen by Newton's successors, who were completely under the spell of his teaching. Or they could take the line that Newton's forces acting at a distance only *appeared* to act thus directly, that they were really transmitted by a medium which permeated space, either by motions or by an elastic deformation of this medium. Thus the desire for unity in our view of the nature of these forces led to the hypothesis of the ether. It certainly led to no advance in the theory of gravitation or in physics generally to begin with, so that people got into the habit of treating Newton's law of force as an irreducible axiom. But the ether hypothesis was bound always to play a part, even if it was mostly a latent one at first, in the thinking of physicists.

When the extensive similarity which exists between the properties of light and those of the elastic waves in ponderable bodies was revealed in the first half of the nineteenth century, the ether hypothesis acquired a new support. It seemed beyond a doubt that light was to be explained as the vibration of an elastic, inert medium filling the whole of space. It also seemed to follow necessarily from the polarisability of light that this medium, the ether, must be of the nature of a solid body, because transverse waves are only possible in such a body and not in a fluid. This inevitably led to the theory of the "quasi-rigid" luminiferous ether, whose parts are incapable of any motion with respect to each

by divesting the ether of its mechanical, matter of its electro-magnetic properties. Inside material bodies no less than in empty space the ether alone, not atomically conceived matter, is the seat of electro-magnetic fields. According to Lorentz the elementary particles of matter are *only* capable of executing movements, their electro-magnetic activity is entirely due to the fact that they carry electric charges. Lorentz thus succeeded in reducing all electro-magnetic phenomena to Maxwell's equations for a field in vacuo.

As regards the mechanical nature of Lorentz's ether, one might say of it, with a touch of humour, that immobility was the only mechanical property which Lorentz left it. It may be added that the whole difference which the special theory of relativity made in our conception of the ether lay in this, that it divested the ether of its last mechanical quality, namely immobility. How this is to be understood I will explain immediately.

The Maxwell-Lorentz theory of the electro-magnetic field served as the model for the space-time theory and the kinematics of the special theory of relativity. Hence it satisfies the conditions of the special theory of relativity, but looked-at from the standpoint of the latter, it takes on a new aspect. If C is a co-ordinate system in respect to which the Lorentzian ether is at rest the Maxwell-Lorentz equations hold good first of all in regard to C . According to the special theory of relativity these same equations hold good in exactly the same sense in regard to any new co-ordinate system C' , which is in uniform translatory motion with respect to C . We are now faced with the awkward question why the system C , which is physically perfectly equivalent to the system C' , should be distinguished from the latter by assuming that the ether is at rest in respect to it. Such an asymmetry of the

interpretation of them. The purely mechanistic view of nature was thus abandoned. This change led to a dualism in the sphere of fundamental concepts which was in the long run intolerable. To escape from it, the converse attempt was made to reduce mechanical concepts to electrical ones. The experiments with β -rays and high velocity cathode rays did much to shake confidence in the strict validity of Newton's mechanical equations.

Heinrich Hertz took no steps towards negating this dualism. Matter appears in his work as the substratum not only of velocities, kinetic energy, and mechanical forces of gravity, but also of electro-magnetic fields. Since such fields are also found in a vacuum—i.e., in unoccupied ether—the ether also appears as the substratum of electro-magnetic fields, entirely similar in nature to ponderable matter and ranking alongside it. In the presence of matter it shares in the motions of the latter and has a velocity everywhere in empty space, the ether velocity nowhere changes discontinuously. There is no fundamental distinction between the Hertzan ether and ponderable matter, which partly consists of ether.

Hertz's theory not only suffered from the defect that it attributed to matter and the ether both mechanical and electrical properties, with no rational connection between them, it was also inconsistent with the result of Fizeau's famous experiment on the velocity of the propagation of light in a liquid in motion and other well-authenticated empirical facts.

Such was the position when H. A. Lorentz entered the field. Lorentz brought theory into harmony with experiment, and did it by a marvellous simplification of basic concepts. He achieved this advance in the science of electricity the most important since Clerk Maxwell,

by divesting the ether of its mechanical, matter of its electro-magnetic properties. Inside material bodies no less than in empty space the ether alone, not atomically conceived matter, is the seat of electro-magnetic fields. According to Lorentz the elementary particles of matter are *only* capable of executing movements; their electro-magnetic activity is entirely due to the fact that they carry electric charges. Lorentz thus succeeded in reducing all electro-magnetic phenomena to Maxwell's equations for a field in vacuo.

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theoretical structure, to which there is no corresponding asymmetry in the system of empirical facts, is intolerable to the theorist. In my view the physical equivalence of C and C' with the assumption that the ether is at rest in respect to C but in motion with respect to C' , though not absolutely wrong from a logical point of view, is nevertheless unsatisfactory.

The most obvious line to adopt in the face of this situation seemed to be the following — There is no such thing as the ether. The electro-magnetic fields are not states of a medium but independent realities, which cannot be reduced to terms of anything else and are bound to no substratum, any more than are the atoms of ponderable matter. This view is rendered the more natural by the fact that, according to Lorentz's theory, electro-magnetic radiation carries impulse and energy like ponderable matter, and that matter and radiation, according to the special theory of relativity, are both of them only particular forms of distributed energy, inasmuch as ponderable mass loses its exceptional position and merely appears as a particular form of energy.

In the meantime more exact reflection shows that this denial of the existence of the ether is not demanded by the restricted principle of relativity. We can assume the existence of an ether, but we must abstain from ascribing a definite state of motion to it, i. e., we must divest it by abstraction of the last mechanical characteristic which Lorentz left to it. We shall see later on that this way of looking at it, the intellectual possibility of which I shall try to make clearer by a comparison that does not quite go on all fours, is justified by the results of the general theory of relativity.

Consider waves on the surface of water. There are

two quite different things about this phenomenon which may be described. One can trace the successive changes which take place in the undulating surface where the water and the air meet. One can also—with the aid of small floating bodies, say—trace the successive positions of the individual particles. If there were in the nature of the case no such floating bodies to aid us in tracing the movement of the particles of liquid, if nothing at all could be observed in the whole procedure except the fleeting changes in the position of the space occupied by the water, we should have no ground for supposing that the water consists of particles. But we could none the less call it a medium.

Something of the same sort confronts us in the electromagnetic field. We may conceive the field as consisting of lines of force. If we try to think of these lines of force as something material in the ordinary sense of the word, there is a temptation to ascribe the dynamic phenomena involved to their motion, each single line being followed out through time. It is, however, well known that this way of looking at the matter leads to contradictions.

Generalising, we must say that we can conceive of extended physical objects to which the concept of motion cannot be applied. They must not be thought of as consisting of particles, whose course can be followed out separately through time. In the language of Minkowski this is expressed as follows—Not every extended entity in the four-dimensional world can be regarded as composed of world-lines. The special principle of relativity forbids us to regard the ether as composed of particles, the movements of which can be followed out through time, but the theory is not incompatible with the ether hypothesis as such. Only we

must take care not to ascribe a state of motion to the ether

From the point of view of the special theory of relativity the ether hypothesis does certainly seem an empty one at first sight. In the equations of an electromagnetic field, apart from the density of the electrical charge, nothing appears except the strength of the field. The course of electro-magnetic events in a vacuum seems to be completely determined by that inner law, and independent of other physical quantities. The electro-magnetic field seems to be the final irreducible reality, and it seems superfluous at first sight to postulate a homogeneous, isotropic etheric medium, of which these fields are to be considered as states.

On the other hand, there is an important argument in favour of the ether hypothesis. To deny the existence of the ether is, in the last analysis, to deny all physical properties to empty space. But such a view is inconsistent with the fundamental facts of mechanics. The mechanical behaviour of a corporeal system floating freely in empty space depends not only on the relative positions (intervals) and velocities of its masses, but also on its state of rotation, which cannot be regarded, physically speaking, as a property belonging to the system as such. In order to be able to regard the rotation of a system at least formally as something real, Newton regarded space as objective. Since he treats his absolute space as a real thing, rotation with respect to absolute space is also something real to him. Newton could equally well have called his absolute space "the ether", all that matters is that another and imperceptible entity, in addition to observable objects, has to be regarded as real, in order that acceleration, or rotation, may be regarded as real.

Mach did indeed try to avoid the necessity for postulating an imperceptible real entity, by substituting in mechanics a mean velocity with respect to the totality of masses in the world for acceleration with respect to absolute space. But inertial resistance with respect to the relative acceleration of distant masses presupposes direct action at a distance. Since the modern physicist does not consider himself entitled to assume that, this view brings him back to the ether, which has to act as the medium of inertial action. This conception of the ether, to which Mach's approach leads, differs in important respects from that of Newton, Fresnel and Lorentz. Mach's ether not only *conditions* the behaviour of inert masses but is also conditioned, as regards its state, by them.

Mach's notion finds its full development in the ether of the general theory of relativity. According to this theory the metrical properties of the space-time continuum in the neighbourhood of separate space-time points are different and conjointly conditioned by matter existing outside the region in question. This spatio-temporal variability of the relations of scales and clocks to each other, or the knowledge that "empty space" is, physically speaking, neither homogeneous nor isotropic, which compels us to describe its state by means of ten functions, the gravitational potentials $g_{\mu\nu}$, has no doubt finally disposed of the notion that space is physically empty. But this has also once more given the ether nonon a definite content—though one very different from that of the ether of the mechanical wave-theory of light. The ether of the general theory of relativity is a medium which is itself free of *all* mechanical and kinematic properties, but helps to determine mechanical (and electro-magnetic) events.

The radical novelty in the ether of the general theory of relativity as against the ether of Lorentz lies in this, that the state of the former at every point is determined by the laws of its relationship with matter and with the state of the ether at neighbouring points, expressed in the form of differential equations, whereas the state of Lorentz's ether, in the absence of electro-magnetic fields, is determined by nothing outside it and is the same everywhere. The ether as conceived by the general theory of relativity passes over into Lorentz's if constants are substituted for the spatial functions describing its state, thus neglecting the causes conditioning the latter. One may therefore say that the ether of the general theory of relativity is derived by relativisation from the ether of Lorentz.

The part which the new ether is destined to play in the physical scheme of the future is still a matter of uncertainty. We know that it determines both material relations in the space-time continuum, e.g., the possible configurations of solid bodies, and also gravitational fields, but we do not know whether it plays a material part in the structure of the electric particles which constitute matter. Nor do we know whether its structure only differs materially from that of Lorentz's in the proximity of ponderable masses, whether, in fact, the geometry of spaces of cosmic extent is, taken as a whole, almost Euclidean. We can, however, maintain on the strength of the relativistic equations of gravitation that spaces of cosmic proportions must depart from Euclidean behaviour if there is a positive mean density of matter, however small, in the Universe. In this case the Universe must necessarily form a closed space of finite size, this size being determined by the value of the mean density of matter.

If we consider the gravitational field and the electro-magnetic field from the standpoint of the ether hypothesis, we find a notable fundamental difference between the two. No space and no portion of space is without gravitational potential, for this gives it its metrical properties without which it is not thinkable at all. The existence of the gravitational field is directly bound up with the existence of space. On the other hand, a portion of space without an electro-magnetic field is perfectly conceivable, hence the electro-magnetic field, in contrast to the gravitational field, seems in a sense to be connected with the ether only in a secondary way, since its formal nature is by no means determined by the gravitational ether. In the present state of theory it looks as if the electro-magnetic field, as compared with the gravitational field, were based on a completely new formal motive, as if nature, instead of endowing the gravitational ether with fields of the electro-magnetic type, might equally well have endowed it with fields of a quite different type, for example, fields with a scalar potential.

Since according to our present-day notions the primary particles of matter are also, at bottom, nothing but condensations of the electro-magnetic field, our modern view of the Universe recognises two realities which are conceptually quite independent of each other even though they may be causally connected, namely, the gravitational ether and the electro-magnetic field, or—as one might call them—space and matter.

It would, of course, be a great step forward if we succeeded in combining the gravitational field and the electro-magnetic field into a single structure. Only so could the era in theoretical physics inaugurated by Faraday and Clerk Maxwell be brought to a satisfactory close.

The antithesis of ether and matter would then fade away, and the whole of physics would become a completely enclosed intellectual system, like geometry, kinematics and the theory of gravitation, through the general theory of relativity. An exceedingly brilliant attempt in this direction has been made by the mathematician H. Weyl, but I do not think that it will stand the test of reality. Moreover, in thinking about the immediate future of theoretical physics we cannot unconditionally dismiss the possibility that the facts summarized in the quantum theory may set impassable limits to the field-theory.

We may sum up as follows—According to the general theory of relativity space is endowed with physical qualities, in this sense, therefore an ether exists. Space without an ether is inconceivable. For in such a space there would not only be no propagation of light, but no possibility of the existence of scales and clocks, and therefore no spatio-temporal distances in the physical sense. But this ether must not be thought of as endowed with the properties characteristic of ponderable media, as composed of particles the motion of which can be followed, nor may the concept of motion be applied to it.

The cause of the formation of meanders in the courses of rivers and of Beer's Lau, as it is called

It is common knowledge that streams tend to curve in serpentine shapes instead of following the line of the maximum declivity of the ground. It is also well known to geographers that the rivers of the northern hemisphere tend to erode chiefly on the right side. The rivers of the southern hemisphere behave in the opposite

way (Beer's law) Many attempts have been made to explain this phenomenon, and I am not sure whether anything I say in the following pages will be new to the expert, some of the relevant considerations are in any case known Nevertheless, having found nobody who thoroughly understood the elementary principles involved, I think it is proper for me to give the following short qualitative exposition of them

First of all, it is clear that the erosion must be stronger the greater the velocity of the current where it touches the bank in question, or the more steeply it falls to zero at any particular point of the confining wall This is equally true under all circumstances, whether the erosion depends on mechanical or on physico-chemical factors (decomposition of the ground) We must concentrate our attention on the circumstances which affect the steepness with which the velocity falls at the wall

In both cases the asymmetry in relation to the fall in velocity in question is indirectly due to the occurrence of a circular motion to which we will next direct our attention I begin with a little experiment which anybody can easily repeat

Imagine a flat-bottomed cup full of tea At the bottom there are some tea-leaves, which stay there because they are rather heavier than the liquid they have displaced If the liquid is made to rotate by a spoon, the leaves will soon collect in the centre of the bottom of the cup The explanation of this phenomenon is as follows — The rotation of the liquid causes a centrifugal force to act on it This in itself would give rise to no change in the flow of the liquid if the latter rotated like a solid body But in the neighbourhood of the walls of the cup the liquid is restrained by friction, so that the angular velocity with which it circulates is less there

than in other places nearer the centre. In particular, the angular velocity of circulation, and therefore the centrifugal force, will be smaller near the bottom than higher up. The result of this will be a circular movement of the liquid of the type illustrated in Fig. 1, which goes on increasing until, under the influence of ground friction, it becomes stationary. The tea leaves are swept into the centre by the circular movement and act as proof of its existence.

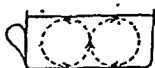


Fig. 1

The same sort of thing happens with a curving stream (Fig. 2). At every section of its course, where it is bent, a centrifugal force operates in the direction of

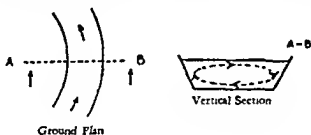


Fig. 2

the outside of the curve (from A to B). This force is less strong near the bottom, where the speed of the current is reduced by friction, than higher above the bottom. This causes a circular movement of the kind illustrated in the diagram. Even where there is no bend in the

river, a circular movement of the kind shown in Fig 2 will still take place, if only on a small scale and as a result of the earth's rotation. The latter produces a Coriolis force, acting transversely to the direction of the current, whose right-hand horizontal component amounts to $2 v \Omega \sin \varphi$ per unit of mass of the liquid, where v is the velocity of the current, Ω the speed of the earth's rotation, and φ the geographical latitude. As ground friction causes a diminution of this force towards the bottom, this force also gives rise to a circular movement of the type indicated in Fig 2.

After this preliminary discussion we come back to the question of the distribution of velocities over the cross section of the stream, which is the controlling factor in erosion. For this purpose we must first realise how the (turbulent) distribution of velocities takes place and is maintained. If the water which was previously at rest were suddenly set in motion by the action of an evenly diffused accelerating force, the distribution of velocities over the cross section would be even at first. A distribution of velocities gradually increasing from the confining walls towards the centre of the cross section would only establish itself after a time, under the influence of friction at the walls. A disturbance of the (roughly speaking) stationary distribution of velocities over the cross section would only gradually set in again under the influence of fluid friction. Hydrodynamics explains the process by which this stationary distribution of velocities is established in the following way — In a systematic distribution of current (potential flow) all the vortex-filaments are concentrated at the walls. They detach themselves and slowly move towards the centre of the cross-section of the stream, distributing themselves over a layer of

increasing thickness. The drop in velocity at the containing walls thereby gradually diminishes. Under the action of the internal friction of the liquid the vortex filaments in the inside of the cross section gradually get absorbed, their place being taken by new ones which form at the wall. A quasi-stationary distribution of velocities is thus produced. The important thing for us is that the adjustment of the distribution of velocities till it becomes stationary is a slow process. That is why relatively insignificant, constantly operative causes are able to exert a considerable influence on the distribution of velocities over the cross section. Let us now consider what sort of influence the circular motion due to a bend in the river or the Coriolis-force, as illustrated in Fig. 2, is bound to exert on the distribution of velocities over the cross section of the river. The particles of liquid in most rapid motion will be furthest away from the walls, that is to say, in the upper part above the centre of the bottom. These most rapid parts of the water will be driven by the circular motion towards the right-hand wall, while the left-hand wall gets the water which comes from the region near the bottom and has a specially low velocity. Hence in the case depicted in Fig. 2 the erosion is necessarily stronger on the right side than on the left. It should be noted that this explanation is essentially based on the fact that the slow circulating movement of the water exerts a considerable influence on the distribution of velocities, because the adjustment of velocities which counteracts this consequence of the circulating movement is also a slow process on account of internal friction.

We have now revealed the causes of the formation of meanders. Certain details can, however, also be deduced without difficulty from these facts. Erosion

will inevitably be comparatively extensive not merely on the right-hand wall but also on the right half of the bottom so that there will be a tendency to assume the shape illustrated in Fig. 3

Moreover, the water at the surface will come from the left-hand wall, and will therefore, on the left-hand side especially, be moving less rapidly than the water rather lower down. It should further be observed that the circular motion possesses inertia. The circulation will therefore only achieve its maximum extent behind the position of the greatest curvature, and the same naturally applies to the asymmetry of the erosion. Hence in the course of erosion an advance of the wave-lines of the meander-formation is bound to take place

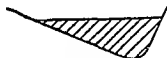


Fig. 3

in the direction of the current. Finally, the longer the cross section of the river, the more slowly will the circular movement be absorbed by friction, the wave-line of the meander-formation will therefore increase with the cross section of the river

The Flettner-ship

The history of scientific and technical discovery teaches us that the human race is poor in independent thinking and creative imagination. Even when the external and scientific requirements for the birth of an

idea have long been there, it generally needs an external stimulus to make it actually happen; man has, so to speak, to stumble right up against the thing before the idea comes. The Flettner-ship, which is just now filling the whole world with amazement, is an excellent example of this commonplace and, for us, far from flattering truth. It also has the special attraction in its favour that the way in which the Flettner rotors work remains a mystery to most laymen, although their action can be explained by mechanical forces which we all believe ourselves to understand instinctively.

The scientific basis for Flettner's invention is really some two hundred years old. It has existed ever since Euler and Bernoulli determined the fundamental laws of the frictionless motion of liquids. The practical possibility of achieving it, on the other hand, has only existed for a few decades—to be exact, since we have possessed practicable small motors. Even then the discovery did not come automatically, chance and experience had to intervene several times first.

The Flettner-ship is closely akin to the sailing-ship in the way it works, as in the latter, the force of the wind is the only motive-power for propelling the ship, but instead of sails, the wind acts on vertical sheet-metal cylinders, which are kept rotating by small motors. These motors only have to overcome the small amount of friction which the cylinders encounter from the surrounding air and in their bearings. The motive power for the ship is, as I said, provided by the wind alone. The rotating cylinders look like ship's funnels, only they are several times as high and thick. The area they present to the wind is some ten times smaller than that of the equivalent tackle of a sailing-ship.

"But how on earth do these rotating cylinders pro-

duce motive power?" the layman asks in despair. I will attempt to answer this question as far as it is possible to do so without using mathematical language.

In all motions of fluids (liquids or gases) where the effect of friction can be neglected the following remarkable law holds good — If the fluid is moving at different velocities at different points in a uniform current, the pressure is less at those points where the velocity is greater, and vice versa. This is easily understood from the primary law of the motion. If in a liquid in motion there is present a velocity with a right-ward direction increasing from left to right, the individual particle of liquid is bound to undergo acceleration on its journey

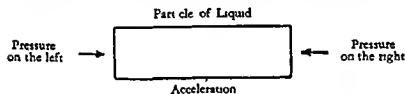


FIG 4

from left to right. In order that this acceleration may take place, a force has to act on the particle in a right-ward direction. This requires that the pressure on its left edge should be stronger than that on its right. Therefore, the pressure in the liquid is greater on the left than on the right when the velocity is greater on the right than on the left.

This law of the inverse ratio of the pressure to the velocity obviously makes it possible to determine the force of pressure produced by the motion of a liquid (or gas), simply by knowing the distribution of velocities in the fluid. I will now proceed to show, by a

familiar example—that of the scent-spray—how the principle can be applied.

Through a pipe slightly widened at its aperture A air is expelled at a high velocity by means of a compressible rubber bulb. The jet of air goes on spreading uniformly in all directions as it travels, in the course of which the velocity of the current gradually sinks to zero. According to our law it is clear that there is less pressure at A, owing to the high velocity, than at a greater distance

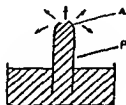


Fig 3

from the aperture; at A there is suction, in contrast to the more distant, stationary air. If a pipe P, with both its ends open, is stood up with its upper end in the zone of high velocity and its lower end in a vessel filled with a liquid, the vacuum at A will draw the liquid upwards out of the vessel, and the liquid on emerging at A will be divided into tiny drops and whisked off by the current of air.

After this preliminary canter let us consider the motion of a fluid around a Flettner cylinder.

Let C be the cylinder as seen from above. Let it not rotate to begin with. Let the wind be blowing in the direction indicated by the arrows. It has to make a certain detour round the cylinder C, in the course of which it passes A and B at the same velocity. Hence the pres-

sure will be the same at A and B, and there is no dynamic effect on the cylinder. Now let the cylinder rotate in the direction of the arrow P. The result is that the current of wind as it goes past the cylinder is divided unequally between the two sides, for the motion of the wind will be aided by the rotation of the cylinder at B, and hindered at A. The rotation of the cylinders gives rise to a motion with a greater velocity at B than at A. Hence the pressure at A is greater than at B, and the cylinder is acted upon by a force from left to right, which is made use of to propel the ship.

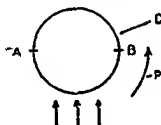


Fig 6

One would have thought that an inventive brain might have hit upon this idea by itself, i e, without an extraneous cause. However, what actually happened was as follows. It was observed in the course of experience that even in the absence of wind the trajectories of cannon balls exhibited considerable, irregular, and variable lateral deflections from the vertical plane through the initial direction of the shots. This strange phenomenon was necessarily connected, on grounds of symmetry, with the rotation of the cannon balls, as there could be no other conceivable reason for a lateral asymmetry in the resistance of the air. After this phenomenon had caused a good deal of trouble to the

experts, a Berlin professor of physics, Magnus, discovered the right explanation about half way through last century. It is the same as the one I have already given for the force which acts on the Flettner cylinder in the wind; only the place of the cylinder C is taken by a cannon ball rotating about a vertical axis, and that of the wind by the relative motion of the air with reference to the flying cannon ball. Magnus confirmed his explanation by experiments with a rotating cylinder, which was not materially different from a Flettner cylinder. A little later the great English physicist Lord Rayleigh independently discovered the same phenomenon again in regard to tennis balls and also gave the correct explanation. Quite a short time ago the well-known professor Prandtl made an accurate experimental and theoretical study of fluid motion around Magnus cylinders, in the course of which he devised and carried out practically the whole of Flettner's invention. Prandtl's experiments were seen by Flettner, and suggested to him that this device might be used to take the place of sails. Who knows if anyone else would have thought of it if he had not?